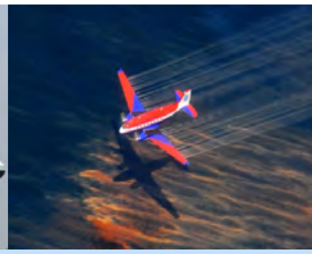
MANUAL ON THE APPLICABILITY OF OIL SPILL DISPERSANTS







VERSION 2

EUROPEAN MARITIME SAFETY AGENCY

Title: Manual on the Applicability of Oil Spill Dispersants
Date of update: September 2009
Date of first version: November 2005

Manual initially prepared as part of EMSA contract EMSA 05-679-RES/04/2005 and updated under EMSA contract EMSA/146/2008.

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SINTEF

INTRODUCTION

This Manual on the applicability of oil spill dispersants has been prepared for EMSA on the basis of the latest available information from a wide variety of sources including Alun Lewis - Oil Spill Consultant, CEDRE and SINTEF, plus information from the 2007 "EMSA Inventory of National Policies regarding the use of oil spill dispersants in the EU Member States" and other sources. This Manual and the associated information included in the software tool (DUET: Dispersant Use Evaluation Tool) represent the best indicative advice that can be provided about the use of dispersants in oil spill response in the absence of incident-specific information. This Manual updates the "Overview Report on the Applicability of Oil Spill Dispersants" which was developed for EMSA in 2005 and distributed to the EU Member States maritime administrations, together with the Decision Support Tool on the Applicability of Oil Spill Dispersants. This updated Manual incorporates recent developments in the field of oil spill dispersants, as well as the comments made from the EU Member States and EFTA countries to the 2005 version of the document.

Every oil spill incident will have specific circumstances that are particular to the oil spill and all these circumstances will contribute to the decision to use, or not to use, oil spill dispersants in the response. The information provided in this Manual and in the software tool has general applicability and should therefore be of use at any oil spill incident. However, all the possible circumstances that may prevail cannot be foreseen and the relevant information will need to be assessed in the light of prevailing circumstances. The question that must be answered is:

"Will the potential benefits of using dispersants (reducing the exposure to spilled oil of shore and near-shore organisms) be greater than the potential risks of using dispersant (exposing marine organisms to the possibility of toxic effects caused by exposure elevated oil concentrations in the water)?"

Clearly, there is no absolute "Yes" or "No" answer to this question; the circumstances of a particular spill (proximity to oil-sensitive resources, water depth etc.) will determine the answer. At some oil spills, dispersant use can be of great benefit, while at other spills their use would be inappropriate as it could cause more damage than it prevents.

A rational decision about dispersant use can only be made with the relevant information from environmental expert sources. It will be necessary to establish which resources (both organisms on the shore/near-shore and those in the water column and benthos) are present and which could be exposed to surface or dispersed oil. The probable effects of exposure to surface or dispersed oil should then be estimated so that the consequences of using dispersants, or not using dispersants, can be assessed. In many instances the precise details of species locations, species populations, seasonal fluctuations etc., may not be known with accuracy, but all available information should be obtained from the relevant sources and analysed so that a decision can be made. There is rarely sufficient time to start the information gathering process at the time of a spill; this should have been done during the preparation of oil spill contingency plans, but a network of the relevant experts should be able of providing timely advice.

This Manual is intended to provide guidance on the decision to use, or not to use, oil spill dispersants. The general principles of dispersant use are described in a simple way that should be understood by decision-makers with different levels of expertise in various disciplines. The factors that need to be taken into account are described. This information, plus the specific information and model contained in DUET should enable a rapid decision to be made about dispersant use. This Manual and the DUET software tool will provide “indicative advice”, not absolute certainty when used to formulate decisions regarding the use of oil spill dispersants. This Manual concentrates on the effectiveness of dispersants and the operational way in which they are used.

The advice derived from using this information must take into account the local environmental sensitivities to the dispersed oil concentrations that will be caused by the successful use of dispersants. The DUET software tool contains an oil spill model that estimates dispersed oil concentrations, as well as surface water area oiled. However, the particulars of the environment and resources in the spill area need to be considered carefully before a decision regarding how best to respond to a spill can be made.

The user should read this Manual on the Applicability of Oil Spill Dispersants before using the DUET. DUET is a software programme including an oil spill model that allows the user to compare scenarios with and without dispersant applications for spills of various types of crude oils and refined oil. The software models the fate and trajectories of oil and its components in space and time. This can provide guidance on the potential impacts of oil when spilled at sea and treated with dispersant or not.

The estimation procedure described in this Manual is not a substitute for carrying out specific weathering studies and dispersant testing with individual crude oils or refined oil products that might be spilled. However, it does allow the behaviour and dispersibility to be estimated, with various degrees of confidence, for oils that have not been tested. DUET also contains rapid access to all the information contained in tables in this document.

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1. BASIC CHARACTERISTICS OF OIL SPILL DISPERSANTS

Oil spill dispersants are liquids that are sprayed onto spilled oil on the sea with the intention of causing the oil to be dispersed into the water column. Whether or not this is a valid oil spill response method depends on the particular circumstances of the oil spill and these are discussed in more details in the following sections of this report.

1.1 Chemical composition of oil spill dispersants - the principles

All oil spill dispersants are blends of surfactants in solvents.

- Surfactants (or surface active agents) are chemical compounds with molecules composed of two dissimilar parts; a "water-loving" (hydrophilic) part and an "oil-loving" (oleophilic) part. Surfactants act as a 'chemical bridge' between oily materials and water and enable these two phases to mix with each other more easily.

  There are many thousands of individual surfactants. Some are natural (there are natural surfactants in milk) and many are man-made, or synthetic. Some surfactants are familiar to us in everyday use; soap is a simple surfactant. Soap helps to clean dirt, fats and greasy materials from our skin and other surfaces by making it easier for these materials to be transferred into water during washing. The surfactants in oil spill dispersants are more complex than a simple soap.

  Surfactants with a wide range of properties and uses can be made by chemically combining fatty materials (vegetable oils, for example) with more water-soluble materials (sugars, for example). The first synthetic surfactants were developed in the early part of the 20th century and the number available rapidly expanded in the 1950s and 1960s. The petrochemical ethylene oxide (EO) is often used in the form of PEGs (polyethylene glycols of various molecular weights) to introduce a water-soluble part to a fatty material. There are a huge number of possible combinations of (i) fatty materials, of different molecular weight, chemically bound to (ii) various water-soluble entities and then modified by the addition of (iii) different proportions of EO. The composition of synthetic surfactants can therefore be varied to produce the properties required for a particular application.

- Solvents are used to dissolve the surfactants (some surfactants are solids) and to reduce the viscosity (many surfactants are high viscosity liquids) so that the dispersant may be sprayed on to the spilled oil.

'Detergents' is the name given to all cleansing products that contain synthetic surfactants. The most popular uses for detergents are washing powders (for clothes) and dishwashing. Washing powders contains synthetic surfactants plus other ingredients, such as 'builders' and enzymes, which are required to make them function well. Detergents are also used for a large number of other applications, both domestic and industrial. The surfactants in dispersants are different from those in general detergents.

1.2 The way that dispersants work

The purpose of using oil spill dispersants is to transfer spilled oil from the surface of the sea into the water column in the form of very small oil droplets.

1.2.1 Natural dispersion

Dispersion of spilled oil at sea is a natural process caused by the action of waves.

Natural dispersion of oil occurs when breaking, or cresting, waves pass through a localized area in an oil slick. The oil slick in that area is broken up by the crest of the wave into oil droplets with a wide range of sizes. The largest oil droplets have the greatest buoyancy and they quickly float back to the sea surface. If these large oil droplets resurface under the slick they will coalesce with the oil still on the surface. If they resurface in ‘clean’ water these oil droplets spread out to form sheen.

As a wave, breaking or non-breaking, passes through or under an oil slick, it does not permanently displace the water in the direction of the wave. The water below a wave moves with circular motion that diminishes with depth. This creates a well-mixed zone below a wave that is half the wave’s length in depth. Smaller oil droplets that have been produced when the oil slick was broken up by a wave crest will float back towards the sea surface much more slowly than larger oil droplets because the rise velocity depends on oil droplet size. The rise velocity of very small oil droplets with diameters less than approximately 0.1 mm is very low and they can become permanently entrained in this well-mixed zone.

Only a very small proportion of the entire area of an oil slick may be affected by cresting waves at any time; the proportion depends on sea-state. Only a small proportion of the oil volume is converted into droplets that are small enough to be retained in the well-mixed layer. The rate of natural dispersion for many oils is therefore quite slow. However, natural dispersion can eventually totally disperse an oil slick if the oil is of low viscosity and the sea is very rough.

If natural dispersion always dispersed spilled oil there would be no need for oil spill response in most cases because the oil would be dispersed if it did not drift ashore first. However, natural dispersion cannot be relied upon to disperse most oil spills. This is because the rate of natural dispersion is greatly reduced and eventually stopped by changes in the characteristics of the oil caused by ‘weathering’ (evaporation of the more volatile oil components and the incorporation of water within the body of the oil to form water-in-oil emulsions). Under most sea conditions, this increase in viscosity stops natural dispersion because the cresting waves cannot break up the high viscosity emulsion into droplets. The cresting waves only distort and deform the patches of emulsion and no oil droplets are formed.

1.2.2 The action of dispersants

The action of dispersants is described in Figure 1.

Surfactants, or surface active agents, are the active ingredients in a dispersant. Surfactants alter the physical and chemical nature of the oil so that the resistance to forming small oil droplets (the interfacial tension) is greatly reduced.

In order to function, the surfactants in a dispersant must be able to penetrate into the spilled oil because they only work from inside the oil. Dispersant is sprayed onto the spilled oil and the solvent helps the surfactants to penetrate into the oil. Once in the oil, the surfactants migrate to where the oil meets the water and the surfactants orientate at the oil / water interface.

This greatly lowers the interfacial tension (or surface free energy) between the oil and the water. The interfacial tension between oil and water - in the absence of surfactants - is high because of the lack of chemical similarity and interaction between the hydrocarbon molecules of oil and the more polar molecules of water. Surfactants act as a 'bridge' with the hydrophilic (water-loving) part of the surfactant molecule residing in the water and the oleophilic (oil-loving) part of the surfactant molecule residing in the oil. The two phases of oil and water are therefore connected through the surfactant molecules.

This produces the potential for easier mixing of oil and water and the creation of very small oil droplets in the water, but some form of mixing energy is required to cause the oil to be converted into small oil droplets in the water. This energy is normally provided by breaking or cresting waves. As a breaking or cresting wave passes through the dispersant-treated oil slick, the oil is broken up into oil droplets with a wide range of sizes. Without the surfactants from the dispersant, most of the oil droplets will be quite large and will rapidly resurface.

The addition of surfactants from the dispersant into the spilled oil allows the breaking, or cresting, wave to convert a much higher proportion of the oil volume into much smaller oil droplets. The smaller oil droplets will be retained in the upper few metres of the water column by the water movement associated with any wave action - be it breaking or non-breaking waves. The low buoyancy of the small oil droplets causes them to rise only very slowly through the water and they are repeatedly pushed back down into the water column by the downward motion of the water.

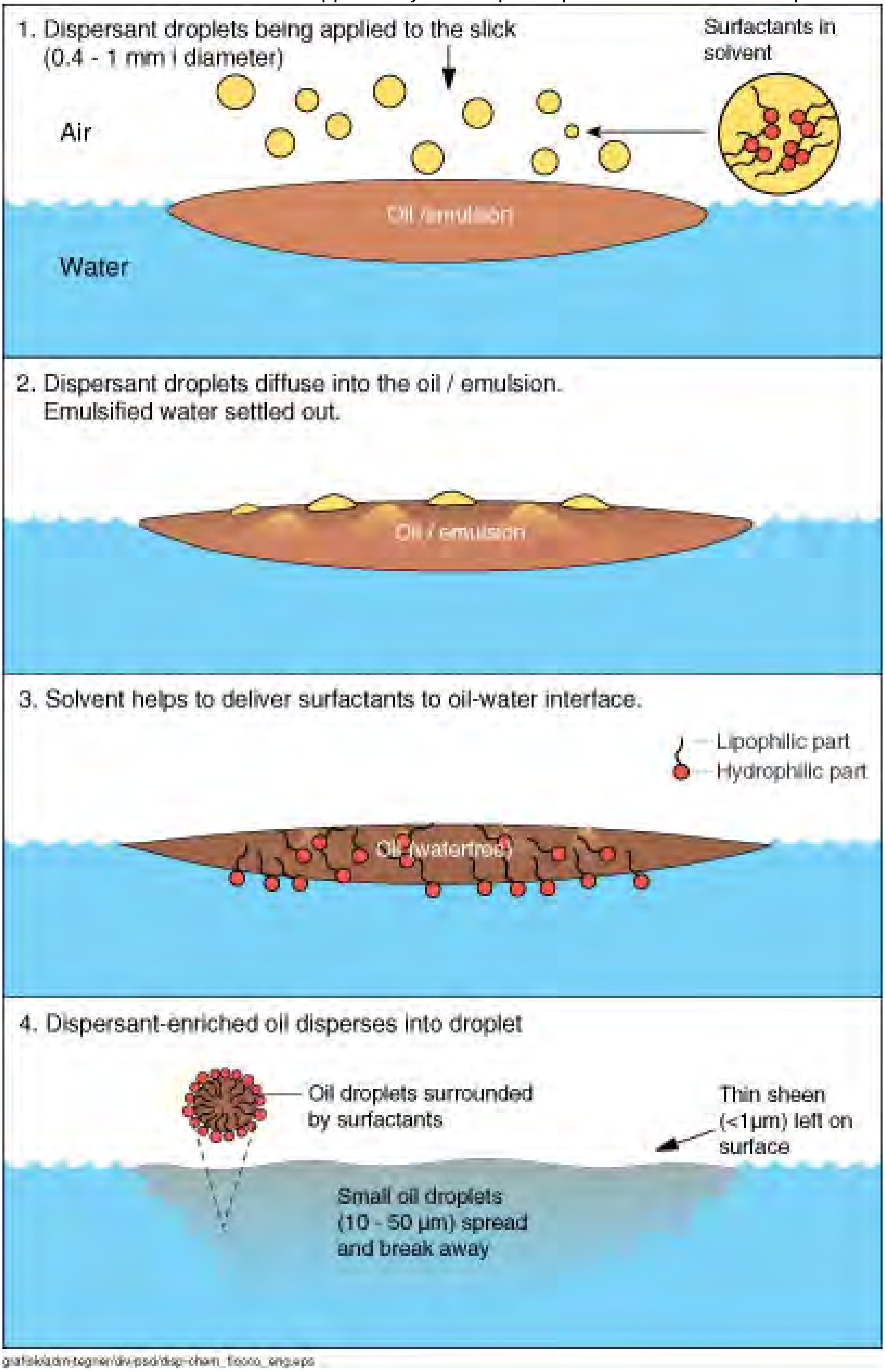


Figure 1. The action of dispersants

1.3 Generations, types and brands of oil spill dispersants

While all oil spill dispersants are composed of surfactants and solvents, the types of surfactants and types of solvents vary according to the different generations, types and brands of oil spill dispersants. Today's oil spill dispersants are the product of several decades of development. This development has been characterised by an improved understanding about the required properties and by regulations that specify the levels of effectiveness and toxicity that are acceptable.

1.3.1 First generation "dispersants" - detergents used in oil spill response

Products specifically formulated to be used as oil spill dispersants did not exist during the 1960s. Industrial detergents primarily developed for other uses such as cleaning oily machinery or washing vehicles and consisting of a variety of different surfactants dissolved in solvents, were occasionally pressed into service to be used to clean up spilled oil, on a small-scale, whenever the need arose. The *Torrey Canyon* oil spill in 1967 was the first - and last - occasion that industrial detergents were used in oil spill response on a massive scale. About 10,000 tonnes of detergents were used to try and clean the estimated 14,000 tonnes of spilled oil off of the beaches in Cornwall in the UK.

The damage done to the local environment by this massive use of industrial detergents was judged to be worse than the damage inflicted by the spilled oil. This was obviously not the intention and a scientific investigation was immediately carried out. This revealed that the solvents used in these industrial detergents were very toxic to marine and near-shore life. Regulations concerning oil spill dispersants were introduced by the UK government and these specified the acceptable levels of toxicity and effectiveness for oil spill dispersants to be sold or used in UK waters.

These days, the industrial detergents used at the *Torrey Canyon* oil spill clean-up would not be allowed to be used as oil spill dispersants because they would not meet the toxicity or effectiveness criteria of the various national regulations.

1.3.2 Second generation dispersants: The first true oil spill dispersants

The first true oil spill dispersants, formulations of surfactants and solvents specifically designed for use is dispersing spilled oil at sea, were those developed after the *Torrey Canyon* oil spill. These conformed to the requirements of the UK regulations introduced in 1971. The UK regulations specified an acceptable level of toxicity, a minimum level of effectiveness and the required physical properties.

The essential difference that discriminates the early "second generation oil spill dispersants" from the "first generation" detergents was a much lower toxicity to marine life. This was achieved by using hydrocarbon solvents with a much lower 'aromatics' content. Aromatics are the BTEX compounds; benzene, toluene, ethylbenzenes and xylenes. The solvent in most of these dispersants was "odourless", "non-aromatic" or "low-aromatics" kerosene. They typically contained 10% to 25 % weight of a surfactant of the fatty acid ester type.

In the UK, this type of dispersant was categorised as "UK Type 1", "Hydrocarbon-base" or "Conventional" oil spill dispersant.

These “Conventional”, “Hydrocarbon-base”, or “UK Type 1” dispersants were recommended for use at 1 part of dispersant to 2 - 3 parts of spilled oil. This is a very high treatment rate, requiring 30% to 50% of the spilled oil volume to be added as dispersant.

The need to use so much dispersant on the spilled oil presented logistic challenges when spraying dispersant from boats or ships; a spill of 100 tonnes of oil would require the use 30 to 50 tonnes of a “hydrocarbon-base” dispersant. Ships and boats would therefore spend much time returning to port to pick up more dispersant to spray.

1.3.3 Third generation dispersants or “Concentrate” oil spill dispersants

“Water-dilutable” or “Concentrate” oil spill dispersants.

Another type of dispersant was developed to meet this challenge. The “Concentrate” or “Water-dilutable” dispersants were developed to enable a boat or ship to disperse more oil with the same amount of dispersant by using seawater as an additional solvent, added just prior to spraying.

These dispersants contain a higher amount of surfactant (up to 50% weight) than the “hydrocarbon-base” dispersants and use a glycol ether solvent, instead of kerosene. Because of the higher surfactant content, these “Concentrate” or “Water-dilutable dispersants generally have a much higher viscosity than the “Conventional”, or “Hydrocarbon-base” dispersants.

In order to use the same spraying equipment that was available at that time (the equipment which had been developed for “Conventional” dispersant application), it was necessary to maintain a similar flow rate and the easiest way of achieving this was to dilute the dispersant with sea water. The seawater is added through an eductor system that sucks up seawater into the spray system and mixes it with the “Concentrate” or “Water-dilutable” dispersant as it is sprayed, or is applied with specific equipment composed of 2 pumps (one for the dispersant, one for the sea water). These dispersants can only be used in this way when spraying from boats or ships.

In the UK, a distinction was needed to distinguish this type of dispersant from the “Conventional” or “Hydrocarbon-base” dispersants and this type of dispersant was designated as “Concentrate, Water-dilutable” or “UK Type 2”, oil spill dispersant.

The dispersant was recommended to be used at a treatment rate of 1 part of the seawater plus dispersant mixture (90% volume seawater + 10% volume dispersant) to 2 - 3 parts of spilled oil. This was the same high treatment rate as the UK Type 1 dispersants, except that the dispersant was used as a mixture of 10% volume “concentrate” dispersant (containing all the surfactants plus some solvent) and 90% volume of seawater acting as an additional solvent.

"Concentrate" oil spill dispersants

As the operational limitations of spraying dispersants from boats and ships, caused mainly by the relatively slow speed, became appreciated, work was carried out on spraying dispersants from aircraft, both helicopters and fixed-wing. The addition of seawater as an extra solvent to reduce the viscosity of the dispersant is not feasible when spraying from aircraft and the dispersant needs to be used undiluted or 'neat'.

In addition, it was found that the dilution of the dispersant with seawater reduces the efficiency of the dispersant, especially when the dispersibility of the spilled oil is low. It was also found that some of the "Concentrate, Water-dilutable", "UK Type 2" dispersants were effective when used undiluted at a much lower treatment rate than had previously been recommended. In addition, new dispersants were formulated to meet the higher standard of effectiveness required of this type of dispersant.

The UK introduced a third type classification of dispersants: "Concentrate" or "UK Type 3"dispersant.

This type of dispersant is recommended for use at a treatment rate of 1 part of dispersant to 20 to 30 parts of spilled oil. 100 tonnes of spilled oil could, in theory be treated with 3 to 5 tonnes of dispersant, although the practicalities of dispersant spraying at sea means that some dispersant is inevitably wasted because it misses the oil. Practical experience has shown that a dispersant treatment rate of 1 part dispersant to 10 or 20 parts of spilled oil is often needed, although lower treatment rates, such as 1 part dispersant to 50 parts of spilled oil, or even 1 part of dispersant to 100 parts of spilled oil, can be effective with low viscosity oils.

The capital investment in aircraft dedicated to spraying oil spill dispersants can be very high and only a limited number of response organisations have such a capability. Many oil spill response organisations continue to use boats and ships to spray dispersants.

Dispersant manufacturers have subsequently developed formulations that can be sprayed from both boats and ships with water dilution (as a UK Type 2 dispersant), or sprayed undiluted (as a UK Type 3 dispersant) from aircraft, boats and ships. Many of these dispersants available today are therefore classified as "Concentrate" dispersants or in the UK as "UK Type 2/3 Concentrate" dispersants

1.3.4 Brands and ranges of oil spill dispersants

Low toxicity oil spill dispersants have been available for about 30 years. During this period they have evolved from the "Hydrocarbon-base" or "Conventional" type, through the "Water - dilutable or Concentrate" type to the "Concentrate (UK Type 2/3)" dispersants that are available today.

For example, the "Finasol" range, now marketed by Total, progressed from Finasol OSR 2 (a "Conventional", "Hydrocarbon-base" or UK Type 1 dispersant), through improved versions of the same type of dispersant (Finasol OSR 3, 4, 7 and 12) to Finasol OSR 5 (a "Concentrate", "UK Type 2/3 dispersant"). This was subsequently improved to produce Finasol OSR 51 and 52 and, most recently, Finasol OSR 61 and 62. All the dispersants are of the Finasol brand, but they cover the full range of generations and types of dispersants available.

Other dispersant manufacturers have followed a similar evolution of their dispersant product range. Dasic International Limited used to produce Dasic Slickgone LT (for Low Toxicity), a “Conventional” or “Hydrocarbon-base”, “UK Type 1 dispersant”. This was supplanted by Dasic Slickgone LTE and Dasic Slickgone LTS which were also “Conventional”, “UK Type 1” dispersants.

Dasic then developed Dasic Slickgone LTSW, a “Concentrate”, “UK Type 2/3 dispersant”. The Dasic range was then extended to include Dasic Slickgone NS, particularly effective on spills of North Sea crude oils. The latest addition to the Dasic range is Dasic Slickgone EW, said to be particularly effective on water-in-oil emulsions formed by spilled oil. All the products are Dasic Slickgone dispersants, but they should not be confused as being the same or equivalent.

All three types of dispersants are still available today:

- “Conventional”, “Hydrocarbon-base” or “UK Type 1” dispersants that can be useful in the minor role of shoreline clean-up
- “Concentrate Water-dilutable” or “UK Type 2” dispersants that can be sprayed from boats or ships.
- “Concentrate”, “UK Type 2/3” dispersants can be sprayed from aircraft and ships.

The salient points about the different generations and types of oil spill dispersants are presented in Table 1.

Description and Generation	UK Type	Sprayed from	Recommended treatment rate	Comments	Current Availability
First generation dispersants		Ships, boats, onshore	**High treatment rate** 30 - 50% dispersant as volume of spilled oil or 1 part dispersant to 2 to 3 parts oil	Industrial detergents with solvents that are too toxic to be used to be used as dispersants	No longer used as oil spill dispersants
"Conventional" or "Hydrocarbon-base" or "Second generation dispersants"	UK Type 1 "Conventional" or "Hydrocarbon-base" dispersant	Ships, boats, onshore	**High treatment rate** 30 - 50% dispersant as volume of spilled oil or 1 part dispersant to 2 to 3 parts oil	**Low toxicity** **High treatment rate**	Available
"Concentrate" or "Third generation dispersants"	UK Type 2 "Water-dilutable concentrate dispersant	Ships and boats	10% solution of dispersant in seawater to 2 to 3 parts oil Equivalent to 1 part dispersant to 20 to 30 parts oil	**Low toxicity** **High treatment rate** when diluted with water and can only be sprayed from ships and boats in this way.	Available
	UK Type 3 "Concentrate" dispersant	Aircraft, ships and boats	**Low treatment rate** 3 to 5% dispersant as volume of spilled oil or 1 part dispersant to 20 to 30 parts oil	**Low toxicity** **Low treatment rate** Used undiluted (or 'neat')	Available

Table 1. Generations and types of oil spill dispersants

1.4 Surfactants and solvents used in oil spill dispersants

The surfactants and solvents in oil spill dispersants are not manufactured solely for use in only this application. Various chemical companies manufacture a broad range of surfactants for sale to other companies that formulate dispersants by blending different surfactants with solvents and other materials to produce the final product. All of the surfactants in oil spill dispersants are used in some other products.

The skill of the dispersant formulator is to select the most appropriate two or three surfactants from the thousands available and then blend them in the correct proportions to achieve the required effect. The selection of solvent is also important to produce the desired physical properties. Dispersants are usually formulated to meet the requirements of national regulations that specify a minimum level of effectiveness in a particular test method (with a particular test oil) and a maximum level of toxicity in a specified procedure (with a particular test organism). These requirements can be met by numerous combinations of the various surfactants and solvent available, so not all dispersants contain exactly the same surfactants or solvents. The precise formulations of commercially available oil spill dispersants are proprietary information. Information on the precise formulation of individual dispersants is supplied by the manufacturers to the national authorities that approve dispersants for sale and use, but is not published in open documents.

The type of surfactants used in individual dispersants has been described in scientific papers for some dispersants and is contained in the MSDS (Materials Safety Data Sheets) for some dispersants. The types of surfactants and solvents used in different types of dispersants were described in the 1994 MAFF review of The UK Oil Dispersant Testing and Approval Scheme.

A summary of the types of solvents and surfactants in different generations and UK Types of dispersant is contained in Table 2.

<table>
<tr><th>Generation</th><th>UK Type</th><th>Surfactants</th><th>Solvents</th><th>Current Availability</th></tr>
<tr><td>First generation dispersants</td><td></td><td>(i) Nonylphenol ethoxylates or Tall oil ethoxylates</td><td>KEX (Kerosene extract)
Kerosene</td><td>No longer used as oil spill dispersants</td></tr>
<tr><td>“Conventional”
or
“Hydrocarbon-base”
or
“Second generation dispersants”</td><td>UK Type 1
“Conventional”
or
“Hydrocarbon-base”
dispersant</td><td>(i) Fatty acid esters
(ii) Ethoxylated fatty acid esters</td><td>Light petroleum distillates:
Odourless or de-aromatised kerosene
Low aromatics (less than 3% wt.) kerosene
CAS No. 64742-47-8
EC No. 265-149-8</td><td>Available</td></tr>
<tr><td rowspan="2">“Concentrate”
or
“Third generation dispersants”</td><td>UK Type 2
“Water-dilutable concentrate dispersant</td><td rowspan="2">(i) Fatty acid esters or sorbitan esters such as Span™ series
CAS No.1338-43-8
(ii) Ethoxylated fatty acid esters (PEG esters) or ethoxylated sorbitan esters such as Tween™ series
CAS No. 103991-30-6
(iii) Sodium di-iso-octyl sulphosuccinate
EC No. 209-406-4
CAS No. 577-11-7</td><td rowspan="2">Glycol ethers such as:
Ethylene glycol
Dipropylene glycol
2-butoxyethanol (Butyl Cellosolve™)
CAS No. 111-76-2
Di-propylene glycol monomethyl ether
CAS No. 34590-94-8
EC No. 252-104-2
Light petroleum distillates:
Hydrotreated light distillates
CAS No 64742-47-8
EC No. 265-149-8</td><td>Available</td></tr>
<tr><td>UK Type 3
“Concentrate”
dispersant</td><td>Available</td></tr>
</table>

Table 2. Typical surfactants and solvents in oil spill dispersants

1.5 Recent innovation and research on dispersants

Dispersants have generally been formulated to pass the minimum requirements of the test procedures required in the various national regulations. As new generations, or UK Types, of dispersant have been introduced, the minimum requirement for effectiveness as assessed by various laboratory tests has been raised.

For example, in the UK, modern “Concentrate”, “UK Type 3” dispersants are required to achieve a minimum of double the percentage effectiveness (as assessed in the WSL test method using a specified test oil) at one-tenth of the treatment rate than that required for the “Conventional”, “UK Type 1” dispersants. Considered in this way, it is not unreasonable to say that the modern “Concentrate” dispersants are approximately twenty times as effective as the older “Conventional” dispersants. However, this cannot be directly translated to dispersant performance on spilled oil at sea and there are other factors to be considered. Only “Concentrate” dispersants can be sprayed from aircraft; “Conventional” dispersants cannot. Spraying dispersant from aircraft has brought a large number of operational advantages.

The fact that all modern dispersants have to pass the same minimum requirements in laboratory effectiveness tests does not indicate that all “Concentrate” dispersants are the same, or that they will exhibit the same degree of performance with all spilled oils at sea.

One area of recent research on dispersants has attempted to relate the percentage effectiveness in simple laboratory tests to the actual performance of dispersants sprayed onto weathered oils of various types at sea in different sea states. A precise correlation has proved elusive; it is relatively easy to determine whether or not a dispersant is causing an oil to disperse at sea, but it is a much more difficult job to quantify the amount of oil dispersed at any particular stage of the dispersion process. The results obtained so far have indicated that some dispersants are better than others, particularly when dealing with highly emulsified oils at low treatment rates. This work has yet to be translated into more stringent effectiveness requirements for regulatory purposes.

Another area of research has been to expose various marine organisms to realistic exposure regimes (of concentrations and times) of the slightly water soluble oil components that are made more readily available by dispersion of the oil. These experiments are often called WAF (Water Accommodated Fraction) exposure experiments. The aim has been to determine whether any subtle, long-lasting effects may be caused by exposure of some marine organisms to dispersed oil that would not be detected by the standardized toxicity test protocols. No such effects have yet been found, but there is always a problem in science in trying to prove a negative.

The currently available dispersants are effective - within certain limitations - if they are used in the correct way. There is little reason to produce dispersants that are significantly more effective than those currently available and there are inherent operational difficulties that would need to be overcome. A dispersant that would be as effective as modern “Concentrate, but at a lower treatment rates could conceivably be formulated, but it would be very difficult to apply it effectively with the currently available spraying equipment and it would undoubtedly be very expensive. Most research is therefore concentrated in learning how to use existing dispersants more effectively rather than creating a ‘leap forward’ in dispersant formulation.

1.6 Recent experiences and developments

In the last 2 years since the first version of this manual was published there have been several developments and events on the topic of oil spill dispersants:

1.6.1 EMSA Inventory and Dispersant Workshop

A desire for standardisation and harmonisation among Member States with respect to dispersant testing and approval methods has been emphasised. EMSA, in close co-operation with other experts, prepared a paper summarising in detail the current status of dispersant testing and approval procedures in the EU. These findings were discussed in detail at the second EMSA workshop on Dispersants in May 2008. Recent developments in dispersant usage and current R&D were also presented. The agreed way forward towards a more harmonised approach for dispersant testing and approval procedures in the EU was through setting-up a Technical Correspondence Group (TCG) facilitated by the Agency.

1.6.2 Canadian wave tank experiments

Following the publication of the U.S. National Research Council's report "Understanding Oil Spill Dispersants: Efficacy and Effects" in 2005, a wave tank was constructed at the Bedford Institute of Oceanography in Canada specifically to address the energy dissipation rate caused by waves of various types and the effect of wave energy on dispersed oil droplet size. The wave tank is 32 metres long, 0.6 metres wide and 1.5 metres deep. A computer-controlled wave generator enables breaking waves of well-characterised intensity to be created within the tank. Several studies of dispersant action have been completed in this tank during the period from 2006 to 2008 and others will be conducted in the coming years. Initial results have shown that non-breaking waves move the oil about on the water surface and breaking waves are required to cause dispersion of dispersant-treated oil and that the presence of dispersant greatly reduces the oil droplet size produced by dispersion in a breaking wave.

1.6.3 Further dispersant testing at Ohmsett

Following testing in the period from 2000 to 2005, testing of the effects of dispersants has continued at the OHMSETT (Oil and Hazardous Materials Simulated Environment Test Tank) facility in New Jersey, USA. Several studies were conducted during 2006 to 2008 on the effects on non-breaking waves in dispersant-treated oil. The non-breaking waves did not cause any significant dispersion of the oil; breaking waves, even of low amplitude and infrequent occurrence are required for a significant proportion of the oil to be dispersed. This led to a further series of studies to determine whether oil on absolutely calm water and then sprayed with dispersant would subsequently disperse if the sea became rougher; this was found to be the case for several days. However, a sub-surface current in the water below the dispersant-treated oil slick, such as that which would occur as the oil drifted under the influence of wind, would slowly remove the dispersant from the oil, leading to a lack of dispersion if the sea got rougher after one or two days.

1.6.4 Possibility of using dispersants on oil spilled in ice

The increase in oil exploration and production activities in Arctic seas has led to a further exploration of the possibilities of using dispersants on oil spilled among ice. Several research studies have been conducted on this topic and some will continue into the future. Dispersants can become less effective in cold water in some circumstances, principally because the viscosity of the spilled oil is increased at low temperature. However, dispersants have been found to be effective in very cold water on several oils; low water temperature does not inevitably mean that dispersants will be ineffective. The presence of ice on the sea surface produces operational challenges in applying dispersants and these are being investigated.

1.6.5 Netherlands change of law and attitude to dispersant use

The primary oil spill response method in Netherlands waters has been – and will continue to be – mechanical containment and recovery. In 2006 Rijkswaterstaat (RWS) published a new capacity plan; “For the protection of vulnerable sea and estuarine areas” and the use of oil spill dispersants is described as a viable response option. Since dispersant use in the waters of the Netherlands had not previously been permitted, there was a need to gather together the available information on dispersant use in other countries and regions, so that the defining conditions for dispersant use in the waters of the Netherlands could be determined. An international Workshop was organised and was held on in October 2007.

1.6.6 Development of national dispersant strategies in non-EU countries

Under the auspices of the IMO (International Maritime Organization) and other initiatives, several countries, for example Georgia and Turkey, have been developing their national policies to dispersant use as part of their national oil spill response plans.

1.6.7 Recent oil spills and the use (and non-use) of dispersants

In the 2-year period since the first version of this manual was published there have been several oil spills into the sea.

- In July 2006, bombings in southern Lebanon hit the Jieh electric power plant (30 km south of Beirut). Part of the heavy fuel oil burned. According to the Lebanese authorities' estimate, 10,000 to 15,000 tonnes of unburned fuel oil were spilled onto the shoreline and drifted at sea, pushed by south-westerly winds. The pollution soon extended to impact almost half of the 200 km of Lebanese coastline. Dispersants were not used in the response because continuing military activity prevented any oil spill response at sea.
- On 11 August 2006, the coastal tanker Solar 1, transporting 2,000 tonnes of oil, sank in waters 300 m deep near the island of Guimaras in the Philippines. Over 1,300 tonnes of oil were spilled at sea very rapidly. The coast was heavily polluted by regular release of oil though leaks in the hull. The island was declared a disaster area by the regional authorities. Logs and buoys were deployed by the local inhabitants to protect certain sites. Some dispersants were sprayed onto the main slick, but the effectiveness is not known. Adverse weather conditions delayed response and probably reduced the effectiveness of the dispersants.

- On 18th January 2007, the container ship MSC Napoli, en route from Antwerp to Lisbon, was caught in a storm at the entry to the Channel and suffered structural damage to the hull. The vessel was beached off Branscombe, Devon, UK and a lengthy operation was mounted to remove the 2,318 containers and 3,500 tonnes of bunker fuel oil on board. A small amount (estimated as 9 tonnes) of IFO-380 oil was spilled on January 23rd and this was sprayed with 1 tonne of dispersant. The spraying was judged to be successful.
- The largest oil spill at sea in recent years occurred on 7th December 2007 when the tanker *Hebei Spirit*, laden with 209 000 tonnes of crude oil, was struck by the crane barge *Samsung Nº 1* whilst at anchor about five miles off Taean on the west coast of the Republic of Korea. About 10,500 tonnes of crude oils (Iranian Heavy, Upper Zakum and Kuwait Export) crude oils were released into the sea. The oil polluted three of the four provinces along the western coast of the Republic of Korea. Dispersants were tested, but not used on a large scale in the response.
- During a storm on November 11, 2007, four ships sank and six ran aground in the Kerch Strait between Russia and Ukraine that links the Black and Azov seas. Two oil tankers were damaged, causing a spill of around 2,000 metric tons of fuel oil. Dispersants were not used in the response because of the remote location and very severe weather conditions
- On the morning of 12th December 2007, during oil offloading from the Statfjord A platform in the North Sea (Fig. 1), about 4,300 m^3 standard cubic metres of crude oil was spilled into the sea from a sub-surface pipeline. The accident occurred when the tanker Navion Britannia was loading oil from a loading buoy. Dispersants were not used in the response and the oil dispersed naturally.
- On 16 February 2008 at 23:00, an oil spill occurred at the loading buoy of the FPSO Dalia (around 130 km offshore Angola), during a transfer operation to a tanker. Dispersants were applied to the slick, but details are not available. Recovery operations then began at sea to recover oil that had not been dispersed. No oil came ashore.
- On Sunday 16 March 2008, a pipe leak caused a spill of an estimated 400 tonnes of bunker fuel (IFO 380) during the loading of a vessel at Donges Refinery, Loire-Atlantique, France. The recovery vessel Argonaute was mobilised at the mouth of the Loire River with a trawl net. Two trawlers collected tar balls in the estuary. Several pollution response booms were set up, especially to protect streams. Dispersants were not used in the response.

2 POTENTIAL BENEFITS AND RISKS OF DISPERSANT USE

The purpose of using oil spill dispersants is to transfer spilled oil from the surface of the sea into the water column in the form of very small oil droplets. The smallest oil droplets will be retained in the upper few metres of the water column by the water movement associated with any wave action - be it breaking or non-breaking waves. Currents and other water movements will gradually disperse these droplets on a large area and into a huge volume of water. The greatly increased oil / water interfacial area caused by the conversion of a floating oil slick into very small droplets of oil will:

- Allow naturally occurring micro-organisms to rapidly biodegrade a large proportion of the dispersed oil.
- Increase the risk of direct contact between the dispersed oil droplets and marine life.

The dispersion of the oil droplets and subsequent dilution into a very large volume of water is favourable to the biodegradation process, and reduces the risk of contact between with the marine organisms.

Any consideration of the use of dispersants in response to an oil spill must consider the potential benefits and the potential risks of dispersant use.

- The potential benefit of dispersing spilled oil is that it is removed from the sea surface and will not drift into shallow water or ashore. Most damage is done by spilled oil when it is in shallow water or on the shore. The effect of dispersing spilled oil is beneficial to those habitats and organisms that will not be contaminated by the spilled oil.

- The potential risk of using dispersants is that marine organisms will be exposed to higher levels of dispersed oil (and soluble components from the dispersed oil) than they would have been, if dispersants had not been used. The degree of harm that might be suffered by marine organisms exposed to dispersed oil is a function of exposure conditions (dispersed oil concentration, duration of exposure and the rate of dispersion and dilution), plus the inherent sensitivity of the particular organism to dispersed oil.

The prevailing balance between the potential benefits and risks will depend on several factors. If the spilled oil is removed from the water surface by being dispersed into the water column, the benefit to some resources (for example, sea ducks) on the water surface must be balanced against the potential risk to other resources (for example, shellfish) on the seabed.

It must first be established whether such resources are present or absent in the area that will be affected by the spilled oil. The second stage of the assessment would be to estimate the exposure to the spilled oil that would occur in the location of the spilled oil and the prevailing conditions.

A prime consideration should be water depth and the rate of water exchange. If the water is very shallow and there is little water exchange, for example a sheltered embayment, oil dispersed with the use of dispersants will not be diluted to low concentrations in the water. The dispersed oil would persist at relatively high concentration in the water for a prolonged period. Any organisms present would be exposed to a relatively high concentration of dispersed oil for a prolonged period. If the water is shallow, but the water exchange is high, for example on an ebbing tide, the dispersed oil concentration would initially be quite high, but would decrease rapidly as the tide fell and the dispersed oil in the water was diluted into deeper water. Any organisms present would be exposed to a relatively high concentration of dispersed oil, but only for a relatively short period.

The prevailing sea state is another factor that needs to be taken into consideration. In a calm sea the rate of oil dispersion caused by the use of dispersants will be slow. The dispersed oil concentration immediately below the dispersant-treated slick will rise slowly. If the sea is rough and the spilled oil is relatively 'light' (as many crude oils are), a proportion of the oil will be naturally dispersed and transferred into the water column without the use of dispersants. Marine organisms will be exposed to elevated concentrations of dispersed oil in the water column even if dispersant is not used. The use of dispersant to disperse oil in these conditions would raise the dispersed oil concentration in water to higher concentrations, but the choice is not between (i) no dispersed oil (without dispersant), and (ii) high levels of dispersed oil (with dispersant use).

2.1 NEBA (Net Environmental Benefit Analysis)

There is no absolutely right or wrong answer to the question "Should oil spill dispersants be used on an oil spill?" In some circumstances, the use of dispersants will produce an overall benefit by preventing spilled oil drifting ashore, contaminating sensitive habitats and harming the species that live in these near-shore or coastal habitats. In other circumstances, the use of dispersants may cause some harm to marine organisms without any substantial or significant benefit to other organisms that might be affected by the oil spill.

NEBA is a crucial concept for good dispersant use decision-making. The successful use of dispersants on spilled oil will inevitably cause a significant increase in the concentration of dispersed oil in the water column as a consequence of the oil being removed from the water surface; that is what dispersants do. NEBA stresses that the 'downside' of dispersant use; the potential for negative effects being caused to marine organism by the temporary exposure to elevated dispersed oil concentrations in the water, should be considered in the context of the 'upside' of dispersant use; the spilled oil will not contaminate seabirds at sea or drift and reach shallow water or the shore and cause damage there.

Although often presented as a 'black and white' style of argument; "the use of dispersants harms marine organisms and not using dispersants prevents them from being damaged; therefore dispersants should not be used", this is a gross over-simplification of the realities of oil spill response.

Dispersants would not be considered for use unless spilled oil was present and it is the damage that could be done by the spilled oil (both on the sea surface and dispersed into the sea) that is the main issue. Reducing this damage by effective action is the aim of any oil spill response strategy and dispersants are a tool that can be used. The use of dispersants does require careful analysis, but the consequences of not using dispersants – and thereby failing to prevent the oiling of perhaps sensitive shorelines – needs to be given even weight in the analysis.

The starting point of NEBA is to consider what would be damaged if no response were carried out to an oil spill. Obviously, the future cannot be known with certainty, but with the appropriate expertise it should be possible to estimate the likely outcomes of an oil spill at a particular location under a certain set of prevailing conditions. NEBA should be incorporated in the preparation oil spill contingency plans as an essential part of the process.

NEBA can also be used if an oil spill has occurred. Time will always be of the essence in oil spill response; there will be little time for deliberations by committees. The appropriate experts should be consulted, as quickly as possible, and asked to provide a concise synopsis of the damage that is likely to be caused by the oil spill. This should include probable damage to marine resources, including fisheries and shellfisheries, ecological resources on the shore and in near-shore waters, socio-economic resources and the direct and indirect financial consequences of the oil spill. The aim is to establish an overview of all the damage that might be caused.

The consequences of alternative oil spill response strategies should then be assessed. This should take into account the prevailing practical and operational logistics. Each possible response strategy needs to be examined:

- In view of the assessment of the damage that will probably be caused by the spilled oil is it necessary to carry out any active response? Will monitoring the oil by aerial surveillance be the most appropriate response at this stage of the spill? What would be the consequences of this action?

- If the prevailing sea conditions limit response at sea, will it be sufficient to wait until the oil comes ashore and recover it from the beach? What would have been damaged?

- While it might be best from an ecological point of view to contain and recover the spilled oil, the feasibility of actually doing so needs to be rapidly assessed. Is sufficient equipment (booms and skimmers) available? Can equipment be moved from other locations rapidly enough to be deployed before the oil comes ashore? Where will the recovered oil be stored? And – most importantly – what damage will be prevented by the feasible response? Recovering a small proportion (say 20%) of spilled oil at sea may have very little influence on the overall outcome; a layer of oil on the shoreline that is 4cm thick causes scarcely less damage than a layer that is 5cm thick.

- Is dispersant spraying feasible? Would dispersant work on the type of oil spilled? Would marine organisms be severely impacted by dispersed oil? Would dispersant use prevent the spilled oil from impacting an especially sensitive resource, such as a mud-flat?

All of these considerations need to be made rapidly. Oil spill response is emergency response, not an academic exercise – although the specialised knowledge of a wide range of experts in different fields will need to be utilised. The probable answers to all the questions need not be answered with absolute precision, but reasonable estimates of probable consequences of the response actions need to be made before a balanced overview can be obtained. The response 'solution' that achieves the highest level of damage reduction – as compared to no oil spill response – is the correct response.

The purpose of any oil spill response method - from the use of dispersants to different shoreline clean-up methods - should be to reduce the amount of damage done by an oil spill. The damage might be to ecological resources, such as sea birds and sensitive habitats, or economic damage to resources, such as fisheries or tourism. The concept of Net Environmental Benefit Analysis (NEBA) is that, in some circumstances, it might be reasonable to sustain some damage to a particular resource as the result of oil spill response, provided that the response prevents a greater degree of damage occurring to another resource. NEBA considers the overall damage that might be caused by an oil spill and does not concentrate on one particular aspect.

Any decision to use dispersants is a judgment that dispersant use will reduce the overall impact of a particular spill under the circumstances prevailing at the time. This requires a sound and effective judgment on balancing the advantages and disadvantages of dispersant use, and comparing these with the consequences of other available response methods.

2.2 What is toxicity?

Toxicity can be defined as the negative effects on organisms caused by exposure to a chemical or substance. These negative effects may be lethal (cause death) or sub-lethal (cause negative effects that damage the organism in some way, but do not cause death). Exposure is a function of the concentration of the substance and the period of time for which the organism is exposed to it. Exposure can be acute - exposure to high concentrations of a substance for a short period, or chronic - exposure to low concentrations of a substance for prolonged periods

Various techniques are used to assess toxicity. Acute toxicity of a substance can be assessed by exposing a test group of organisms to a range of concentrations of a substance for a specific period. Typical periods are 24 hours (one day), 48 hours (two days) or 96 hours (four days). The number of organisms that die after the exposure can then be measured and the concentration of a substance that kills half the test population can be calculated. This is the basis of the 96-hour LC_{50} (Lethal Concentration that kills 50% of the test population) toxicity test method.

Death is not a very subtle indicator of toxicity. A population of organisms may be affected by exposure to lower concentrations of substances for shorter periods in a different way. Interference with feeding or breeding behaviour may cause changes in a population without directly killing the individual organisms. Other, more subtle, indicators of toxic effects are also used to assess the toxicity. The lowest level of sensitivity is known as the NOEC - No Observable Effects Concentration. Exposure of an organism to the NOEC of a substance causes no observable effects. The NOEC (or the LC_0, as it could also be described) is difficult to assess accurately and is often estimated as being one-tenth of the LC_{50}, which is easier to assess.

2.2.1 Toxicity of oil spill dispersants

Modern oil spill dispersants have been assessed by standard toxicity testing techniques (LC_{50} testing for 6, 24, 48 or 96 hours) and most have been found to be of relatively low toxicity, or at least less acutely toxic than the spilled oils that they are used to disperse. This is in direct contrast to the “first generation dispersants”, or more accurately, detergents used in an attempt to clean up the oil from the *Torrey Canyon* in 1967; these were much more acutely toxic than the spilled crude oil.

2.2.2 Toxicity of oils

The toxicity of oil is a complex topic. The following section was authored by D. French McCay and is based on a much more comprehensive scientific paper (French-McCay, 2002, *Environmental Toxicology and Chemistry* 21(10), pp. 2080-2094). Interested readers may wish to obtain this reference for further details.

Spilled oil exerts toxic effects because some of the chemical compounds in oil are slightly soluble in water. Elevated concentrations of the lower molecular weight aromatic hydrocarbons i.e., monoaromatics (MAHs) and especially polynuclear aromatic hydrocarbons (PAHs), dissolved into the water are the cause for most of the acute toxicity to aquatic organisms from spilled oil. The principle acutely toxic effect caused by these compounds is narcosis. MAHs and PAHs cause narcosis in aquatic organisms by accumulating in the fatty substances such as the lipids in the cell membranes and disrupting cellular and tissue function.

MAHs are also sometimes referred to as BTEX compounds: benzene, toluene, ethyl benzenes and xylenes. Lower molecular weight aliphatic hydrocarbons may also contribute to toxicity, particularly in gasoline and other products where they form a major portion of the fuel. MAHs are also volatile and evaporate rapidly from spilled oil. Typically, for surface releases of fuel and crude oils, only the PAHs are dissolved in sufficient quantity and remain in the water long enough for their toxic effects to be significant, most of the MAHs having evaporated before they could dissolve into the sea. Other toxic modes of action have been observed for higher molecular weight PAH contamination in sediments over long exposure times, but the primary concern for dispersant use offshore is acute (short-term) exposure of water column biota to potentially toxic concentrations of the lower molecular weight PAHs.

The potential degree of acute toxic effects that could be caused by individual MAHs and PAHs depends on their relative solubility in water and solubility in fat. The more fat-soluble (hydrophobic) the compound, the more it will accumulate in the fatty tissues and therefore the more severe the toxic effect. However a compound that is very soluble in fat will be much less soluble in water, and so the less available to aquatic organisms. Thus, the potential toxic impact is the result of a balance between bioavailability (dissolved-component exposure) and toxicity once exposed. PAHs are more hydrophobic than MAHs, and so are more toxic. There is a continuum from the most soluble and least toxic benzene (simplest MAH) through the naphthalenes (2-ring PAHs) to the 3- and 4-ring PAHs. The more complex 4-ring PAHs are so insoluble that they are not dissolved or bioavailable to a significant extent.

Because of the relative solubility and volatility of various MAHs and PAHs, and the relative concentrations of the various compounds in oil, most of the acute toxicity is caused by substituted naphthalenes (C2- and C3-naphthalenes). However, all the compounds in the mixture contribute in some degree to toxicity

The relative concentration of substituted naphthalenes in different crude oils and refined oil products varies over a wide range:

- Gasoline contains a very high proportion of MAHs and some substituted naphthalenes, but the MAHs evaporate rapidly into the air if gasoline is spilled at sea.
- Distillate diesel fuels (such as MDO (Marine Diesel Oil) and MGO (Marine Gas Oil) contain a high proportion of substituted naphthalenes; these are liable to dissolve into the water to cause toxic effects.

- The substituted naphthalenes concentration in crude oils varies over a wide range; ‘light’ crude oils contain more than ‘heavy’ crude oils.
- Heavy fuel oils (‘black oils’) contain much lower concentrations of substituted naphthalenes, although the lower viscosity grades of residual bunker fuel oils have added diluents oils (often MDO) that increase the substituted naphthalenes concentration.

The potential for acute toxicity caused by exposure to spills of different oils therefore varies over a wide range. Diesel fuel being of low viscosity, and so easily dispersed, as well as containing the highest proportion of substituted naphthalenes has the highest potential for toxic effects. Residual fuel oil being of high viscosity, and so not easily dispersed, and having the lowest proportion of substituted naphthalenes has the lowest potential for toxic effects.

Toxicity varies with time of exposure, the LC_{50} (Lethal Concentration for 50% of exposed organism) decreasing as exposure time increases. This is due to the accumulation of toxicant over time up to a critical tissue concentration that causes mortality. The accumulation is slower for more hydrophobic compounds. The accumulation is also slower at colder temperature. Thus, for brief exposures at low temperature, toxic effects require a higher concentration than would be necessary at higher temperature or for instances where exposure times are longer. Because the aromatic mixture in fuel and crude oils has a toxicity equivalent to C2- or C3-naphthalenes, and oil exposures are hours to days, duration and temperature of exposure need to be considered to determine an appropriate LC_{50} and toxic effects to water column organisms.

Species vary in their sensitivity to the narcotic chemicals in oil. For a turbulent release or after natural or dispersant-induced entrainment, the LC_{50} for PAH exposure of >4 days is about 50 µg/L total PAH for the species of average sensitivity. Species sensitivity varies from 6 to 400 µg/L (ppb) of PAH, covering 95% of species.

2.2.3 Toxicity of oil affected by the use of dispersants

Dispersing spilled oil converts the oil from a surface slick to a plume or ‘cloud’ of dispersed very small oil droplets in the water column. These oil droplets might be ingested by filter feeding organisms, such as copepods, oysters, scallops and clams.

Successful application of dispersants can reduce oil-spill impacts to wildlife and shoreline habitats, with the trade-off of dispersed oil potentially causing impacts to water column organisms. Oil-spill fate and transport modelling, such as those implemented by the DUET software accompanying this manual, can be used to evaluate the maximum potential water column hydrocarbon concentrations and potential for impacts of oil spills with dispersant use in offshore waters.

The increase in the surface area of the oil increases the rate at which partially water-soluble chemical compounds in the oil are transferred into the sea. The localized concentration of these potentially toxic Water Accommodated Fraction (WAF) compounds will rise before they are diluted away. This is the justification for the argument that dispersants can never be a valid oil spill response because the use of dispersants, if they are effective, will inevitably cause an increase in the dispersed oil concentration in the water column and this will lead to toxic effects on marine life.

However, it is important to distinguish between:

- the increased potential for toxic effects to occur, and
- the possibility of toxic effects actually occurring.

Dispersed oil concentrations will certainly be higher if dispersants are used, than if they are not. This does not mean that the dispersed oil concentrations will be high enough, or persist for long enough, to cause actual toxic effects. Most spilled oils will naturally disperse to some degree in the initial stages of an oil spill, before the oil becomes emulsified. The successful use of dispersants will obviously increase the concentration of dispersed oil in the sea. However, this is a matter of degree rather than an absolute difference; some spilled oil is likely to naturally disperse even if dispersants are not used.

In operational use, dispersing oil into the water column by the use of dispersants will expose some marine organisms in a localized volume of water to higher levels of slightly water soluble oil compounds and dispersed oil than they would be exposed to if dispersants were not used. This is often presented as a black and white choice; disperse the oil and cause toxic effects to marine organisms by exposure to dispersed oil, or do not use dispersants and therefore not expose marine organisms to the potentially toxic effects of some oil compounds. However, the true choice is not between:

- no exposure to dispersed oil if dispersants are not used

or

- exposure to dispersed oil only if dispersants are used.

because natural dispersion is a process that proceeds quite rapidly in rough seas with low viscosity oils.

Exposure of some marine organisms to dispersed oil at some concentration will occur even when dispersants are not used. Experience from both experimental field trials and dispersant operations at real spills have shown that dispersed oil will quickly be diluted into the sea. The oil in water concentration rapidly drops from a maximum of 30-50 ppm just below the spill short time after treatment, to concentrations of <1-10 ppm total oil in the top 10-20 meters after few hours.

During the *Sea Empress* incident, off Wales in 1996, which was the largest dispersant spraying operation carried out to date with over 440 tonnes of dispersant sprayed, oil concentrations were monitored in the upper water column; it was found to be:

Time after dispersant application	**Oil concentration in the upper water column (ppm)**
Just after treatment	10
2 day s after treatment	1
1 week after treatment	0.5
1 month after treatment	0.2
3 months after treatment	Background level

A great deal of work has been carried out to devise toxicity test methods that use exposure regimes for test organisms that more closely resemble the real conditions. Toxicity tests performed with more realistic “spike-exposure” regimes show that the use of dispersants does not cause significant effects at dispersed oil concentrations of lower than 5-10 ppm with embryos and larvae.

A level of 10-40 ppm-hours (concentration in ppm multiplied by exposure in hours) was found to produce no significant effects on higher marine life, such as older larvae, fish and shellfish.

Provided that dispersants are used to disperse oil in water where there is adequate depth and water exchange to cause adequate dilution, there is little risk of dispersed oil concentrations reaching levels for prolonged periods that could cause significant effects to most marine creatures.

2.3 Biodegradation of dispersed oil

It has been known for a long time that spilled oil will be biodegraded quite rapidly if conditions are suitable. The naturally occurring micro-organisms responsible for the biodegradation of spilled oil require oxygen and nutrients in proportion to the amount of available oil. As these micro-organisms exist in the water and must colonize the oil surface that is exposed to the water, one of the factors limiting the rate of biodegradation of a surface oil slick is the area of oil available to them, in proportion to the volume of oil present.

Biodegradation of surface oil slicks is slow because much of the oil is not available to the micro-organisms - it is within the bulk of the oil, even though the slick might be quite thin. Oil dispersed into the upper layers of the water column as a locally low concentration of very small oil droplets maximizes all the opportunities for rapid biodegradation. The surface area of oil exposed to the water is high compared to its volume because of the small droplet size. The local concentration of oil is low compared to the water and this provides the opportunity for a high concentration of oil-degrading micro-organisms to survive without being limited by the available nutrients. Different oil components biodegrade at different rates at sea; some of the simpler chemical compounds biodegrade quite rapidly, but some of the more complicated oil components biodegrade at a very slow rate, if at all.

Oil spill dispersants produce a ‘cloud’ or plume of very small oil droplets in the water column if they have been effectively applied to an oil that is in a dispersible condition. This will produce a much greater surface area of oil available for microbial colonization and subsequent biodegradation, compared to oil on the surface if the sea. The components of dispersant are, in themselves, very biodegradable.

As an oil is biodegraded, some of the chemical compounds will become more “bioavailable”. Some chemical compounds in oil are toxic enough to inhibit the early stages of biodegradation, but the enormous number of microorganisms available in the sea ensures that this is a temporary effect. Eventually the biodegradable oil compounds are converted into biomass and eventually to carbon dioxide and water.

A small proportion of the oil - the larger and heavier molecules - cannot be biodegraded by micro-organisms or used as food by any marine life. It is not toxic and it cannot be processed by marine life - it is biologically inert. This portion of the spilled oil will be present in the marine environment for a very long time. This material will be the asphaltenes and resin components of the oil. It resembles a soft bitumen. It will be dispersed in a very large volume of sea water and may eventually settle to the sea bed over a huge area, where it will join the organic detritus that is composed of dead and rotting flora and fauna. It will eventually become incorporated into sea-bed sediments.

2.4 Quantifying the risk of using dispersants

All the evidence that has been gathered during over 30 years of research indicates that there is generally only a small risk to marine life when dispersing spilled oil.

This is not to say that there is no risk, or that the risk should be ignored. It cannot (and should not) be denied that dispersed oil has the potential to cause toxic effects to marine life. This potential will only be realized if dispersed oil concentrations reach high levels that persist for considerable periods of time. The risk of using dispersants must be quantified to enable rational judgments to be made about dispersant use. This can sometimes be difficult because it involves comparing two hypothetical situations; trying to estimate what damage an oil spill will cause if no response is undertaken, compared to the estimated consequences of using dispersants. In most cases of real oil spills and any response, it has proved extremely difficult to quantify the degree of damage caused, or of the damage that was prevented by response actions. Additionally such a comparison may involve judging the 'value' of different types of resources such as natural resources and socio-economic resources.

Some marine creatures, like shellfish and some small crustaceans, are particularly sensitive to dispersed oil and the partially water-soluble chemical compounds that are liberated when oil is dispersed. There are therefore some situations when using dispersants could cause some ecological damage. However, the greater threat presented by the oil spill must also be borne in mind.

The use of toxicity test results can be combined with computer modelling techniques to produce a quantitative assessment of the likely effects of dispersing oil. The modelling can generate 3-dimensional representations of the dispersed oil and WAF concentration profiles (or concentration profiles of individual chemical compounds from the oil) that will be produced by using dispersants. Furthermore, the models can calculate the differences in water volume to be exposed to water-soluble WAF (mainly BTEX compounds - Benzene, Toluene, Ethylbenzenes and Xylenes) concentrations above the indicated limits for acute toxicity with and without use of dispersants. Knowledge of the marine creatures occupying the affected areas / volume can then be combined with the results from toxicity testing to predict the probable outcome of dispersant use.

Such simulations can never be absolutely accurate, but they now can provide very useful indications of the probable effects of dispersant use. Some uncertainty is inevitable as the location of populations of marine creatures will rarely be known with great precision and will vary from season to season. Predicting the weather is another source of uncertainty. Despite these uncertainties, the information that is gathered as part of environmental sensitivity studies for oil spill contingency planning can be integrated into modelling efforts to provide a good basis for quantifying the risk of dispersant use.

Natural dispersion in action – the Braer incident

In 1993, the *Braer* incident led to the spillage of 85,000 tons of light crude oil (Gullfaks from the Norwegian sector) off the South Shetlands Islands. Due to the nature of the oil, with a low tendency to emulsify, and particularly to the very bad weather and rough seas (the wind speed was 30 - 50 knots for many days) this massive amount of oil was totally and rapidly dispersed in the water column. Some dispersant was sprayed, but the weather conditions prevented dispersant spraying for most of the time.

The dispersed oil in water concentrations in near-shore waters around the wreck were reported as being up to 100 to 50 ppm for the first days, a few ppm 10 days after the wreck and back to the background level 70 days after the incident. In offshore waters, the dispersed oil in water concentrations had decreased to the background level after 30 days. Some dispersed oil did contaminate the top layer of the sea-bed sediment in some areas some distance from the wreck.

The ecological consequences were studied intensively in the aftermath of the incident. No evidence of any major impact on the benthic fauna caused by the exposure to high levels of dispersed oil was found within the affected area. Farmed salmon exposed to high concentrations of dispersed oil were 'tainted' - a temporary sub-lethal effect, but did not die. There was no recontamination by the dispersed oil from the polluted sediment. The short term damage was limited. There were no sub-lethal pathological effects and the effects of oiling on sea-bed communities were surprisingly small. The effects on commercial fisheries (white fish) were small; the oil concentrations in the fish rapidly decreased to background levels. After 18 months, the general conclusion was that there had been limited short-term damage caused by the naturally dispersed oil.

2.5 Situations when and where dispersants should not generally be used

By removing oil from the water surface, dispersants minimize the potential impacts on sea birds and sensitive shorelines such as salt marshes, mangroves and tourist beaches. Many species of free swimming fish are able to detect dispersed oil in the water column at low concentrations and will swim away to avoid it. Localized high concentrations of dispersed oil in the water column, following the use of dispersants, may present a risk to marine organisms that cannot move to avoid it. The concentration of dispersed oil in the water column will rapidly drop, provided that there is sufficient water exchange to dilute the dispersed oil into a much larger volume of water.

In general:

- Dispersants should **not** be used in very shallow water, less than 5 to 10 metres deep because the 'cloud' or plume of dispersed oil will come into contact with the sea-bed and expose benthic organisms (those that live in the mud and sediment) to high concentrations of dispersed oil.

- Marine filter-feeders such as shellfish that eat plankton may ingest the dispersed oil droplets. Dispersants should therefore **not** be used on spilled oil that is directly above shellfish beds.

- Dispersants should not be used on spilled oil that is directly over corals, sea grass and fish spawning areas as these may be highly sensitive to dispersed oil.

- The use of dispersants would **not** normally be recommended in the vicinity of fish cages, shellfish beds or other shallow water fisheries due to the increased risk of 'tainting' (imparting an unpleasant oily taste to the flesh of fish and shellfish.

- The use of dispersants close to industrial water intakes which are normally protected by fixed booms is **not** advisable, since dispersed oil will pass under the booms and may contaminate heat-exchangers.

The factors influencing the decision to use dispersants are seldom clear-cut and the choice is necessarily a compromise between other possible response options, cost-effectiveness and the often conflicting priorities for protecting different resources from pollution damage.

Because the opportunity to use dispersants may be limited, the circumstances when dispersants may or may not be used should be agreed upon before a spill occurs to avoid delays. The NEBA process enables responders to balance the positive and negative aspects of different response options (including leaving to natural processes) according to the priorities for protection, the type of oil and the environmental conditions.

3. SPILLED OILS ON WHICH DISPERSANTS CAN BE USED

There are two basic questions to be asked when considering dispersant use:

(i) Will dispersants 'work' on the spilled oil; i.e. will the spilled oil be dispersed if dispersant are accurately sprayed onto it?

(ii) Will dispersing the oil be better or more harmful than allowing the oil to stay on the sea surface and eventually drift ashore?

There is no point in considering the potential effects of dispersed oil if the dispersant will not work, so the first question to answer must be "Will dispersants work?"

3.1 Will dispersants work?

The aspects to be considered to answer this question include:

- The properties of the oil spilled;
- The degree of 'oil weathering' that has occurred, and is likely to occur;
- The prevailing conditions (of sea-state and temperature).

Careful analysis of all these aspects will enable the period of time during which dispersant spraying would be effective - the "window of opportunity" for dispersant use - to be estimated.

3.1.1 Spilled oil properties

Most crude oils can be dispersed, provided that they are sprayed with dispersant soon after they have been spilt. Low to medium viscosity crude oils (with a viscosity of less than 1,000 mPa.s at the prevailing sea temperature) can be easily dispersed. Higher viscosity oils are less easy to disperse as the effect of increasing oil viscosity is to slow down the dispersion process that is being caused by the prevailing wave action. Crude oils with a pour point 10-15°C above sea temperature cannot be dispersed because they may solidify at sea.

It has been known for many years that it is more difficult to disperse a high viscosity oil than a low or medium viscosity oil. Laboratory testing had shown that the effectiveness of dispersants is related to oil viscosity, being highest for modern "Concentrate, UK Type 2/3" dispersants at an oil viscosity of about 1,000 or 2,000 mPa.s and then declining to a low level with an oil viscosity of 10,000 mPa.s. It was therefore considered that some generally applicable viscosity limit, such as 2,000 or 5,000 mPa.s, could be applied to all oils.

Recent work has shown that this is not the case. Modern oil spill dispersants are generally effective up to an oil viscosity of 5,000 mPa.s or more, and their performance gradually decreases with increasing oil viscosity; oils with a viscosity of more than 10,000 are, in most cases, no longer dispersible. However, oil composition also appears to be a very important factor as are the amount of energy from the waves, dispersant type and dispersant treatment rate are also very important factors. Many heavy oils have complex flow properties at the temperatures encountered on the sea. A simple viscosity value is not a good indicator of flow properties for these oils when they are at low temperatures.

3.1.2 Dispersion of Heavy Fuel Oils

Dispersion of the lighter grades of Intermediate Fuel Oils (IFOs), such as IFO-30 and IFO-80 is possible. Some medium fuel oils (MFO, IFO-180 or No. 5 Fuel oil) may also be dispersed, especially in warmer waters and rougher seas. Some heavy fuel oils (HFO, Bunker C, No. 6 Fuel Oil) might be dispersible in very warm seas under some conditions, provided that they are sprayed with dispersant almost as soon as they are spilled, but are unlikely to be dispersible in colder waters. Some Heavy Fuel Oils have been found to be dispersible up to a viscosity of 20,000 mPa.s, but this is very dependent on the composition of the fuel oil. The viscosity of any oil alters with temperature; oils have a higher viscosity at low sea temperatures than at high sea temperatures and Figure 2 illustrates the change in viscosity (in mPa.s) for a variety of heavy fuel oils.

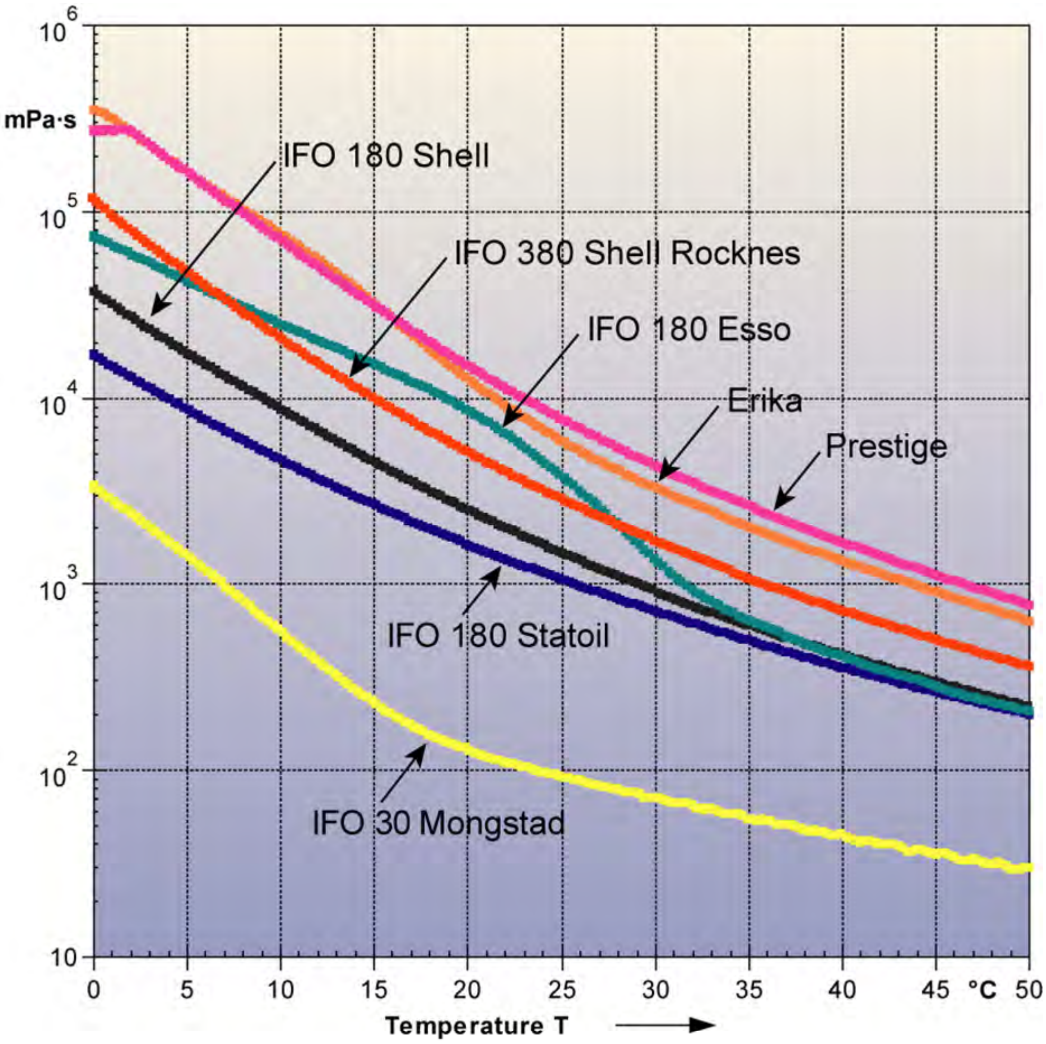


Figure 2. The effect of temperature on Heavy Fuel Oil viscosity

Heavy industrial fuel oils, such as that spilled at the Erika incident, cannot be dispersed; they have far too high a viscosity and also tend to float as very thick patches on the sea, too thick to be sprayed with dispersant. However, the grade of a fuel oil (which is defined by the oil viscosity at 50ºC or 100ºC) is only a very approximate indication of the oil viscosity and dispersibility at sea temperature. The maximum permitted pour point for MFOs and HFOs is +30ºC. Not all fuel oils have a high pour point, but those that do would be solid below this temperature and will therefore not be dispersible.

3.1.3 The general effect of oil viscosity on dispersant effectiveness

Table 3, which is taken from the CEDRE publication "Traitement aux dispersants des nappes de pétrole en mer", gives an indication of how dispersants of different generations and types are likely to be effective on oils of different viscosity.

It should be noted that even modern "Concentrate" dispersants will be relatively ineffective when high viscosity oils when used in the water-diluted (UK Type 2) way.

Only modern "Concentrate" dispersants used on their own, as 'neat' or undiluted with seawater, are likely to be effective on high viscosity oils at reasonable treatment rates.

Dispersant			Sprayed from	Spilled oil			
				Viscosity of spilled oil (in cSt at sea temperature)			
Generation	Description	UK Type		Less than 500	500 - 5,000	5,000 - 10,000	Greater than 10,000
				Possibility for dispersion			
				Generally easy	Generally possible	Sometimes possible	Generally impossible
Second	"Conventional" or "Hydrocarbon-base"	UK Type 1	Ships, boats, onshore	Dispersant effective at 30% volume treatment rate	Dispersant effective at 30% - 50% volume treatment rate	Dispersant possibly effective at 100% volume treatment rate	Ineffective
Third	"Concentrate" or "Water-dilutable concentrate"	UK Type 2	Ships and boats	Dispersant effective at 50 - 100% volume treatment rate	Ineffective	Ineffective	Ineffective
	"Concentrate"	UK Type 3	Aircraft, ships and boats	Dispersant effective at 5% volume treatment rate	Dispersant effective at 5% - 10% volume treatment rate	Dispersant effective at 10% - 15% volume treatment rate	Ineffective

Table 3. Likely dispersant effectiveness as a function of spilled oil viscosity.

3.1.4 'Weathering' of spilled oil

The initial viscosity of any oil can only be used as an indicator of the likely performance of dispersants. The use of dispersants on spills of most crude oils is likely to be successful, provided that the dispersant can be sprayed before the oil has 'weathered' to a substantial degree. The way that the composition and physical properties change with time as an oil 'weathers' (Figure 3.) is the main characteristic that will determine the dispersibility of oil.

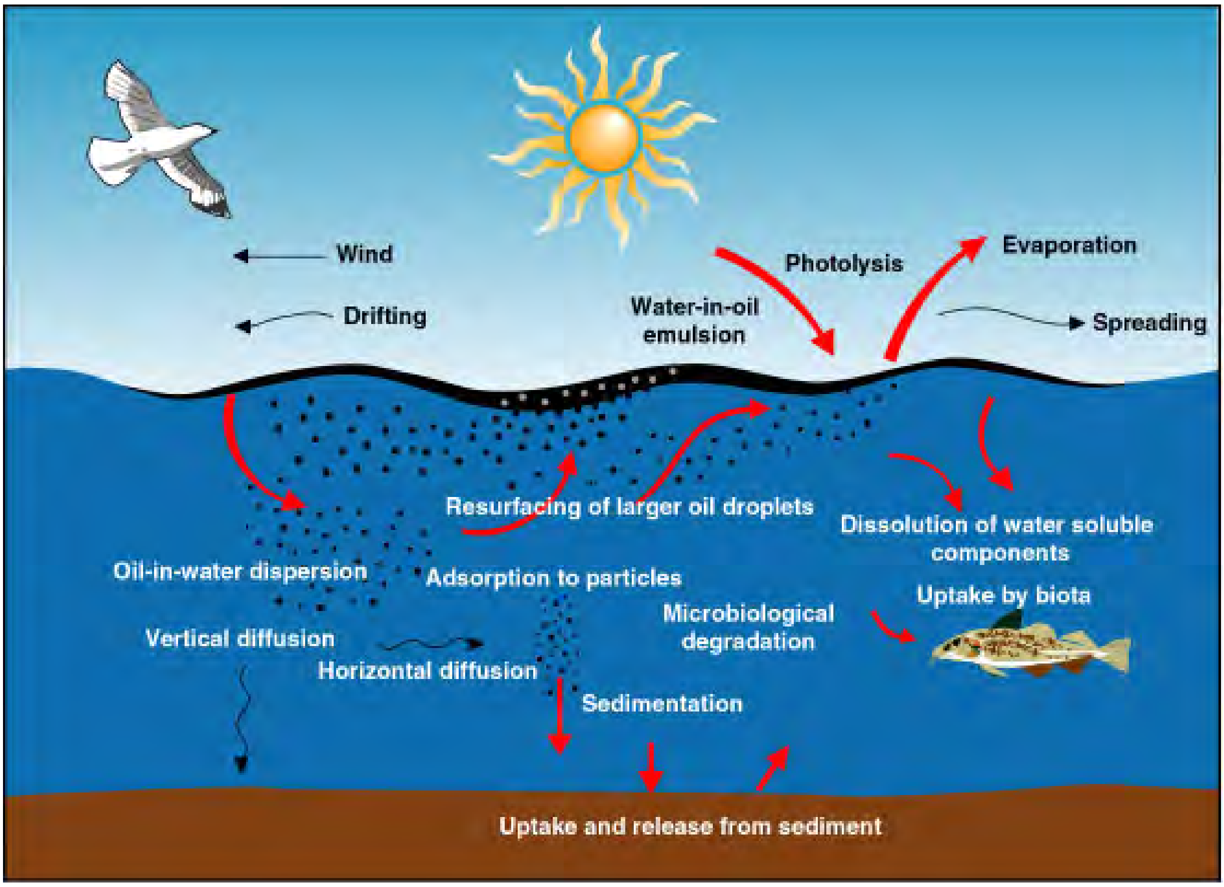


Figure 3. Weathering processes of spilled oils

The physical properties and composition of spilled oil changes as the more volatile oil components are lost by evaporation and as the oil incorporates water droplets to from water-in-oil emulsion. The flexing and compression of the emulsified oil, caused by wave action, reduces the average size of the water droplets within the oil. Asphaltene components precipitate from the oil to form a stabilizing coating around the water droplets and the emulsion becomes more stable with time. All of these processes cause an increase in the viscosity and stability of the emulsified oil and can cause dispersants to become less effective with time. The rate at which these processes occur depends on oil composition and the prevailing temperature, wind speed and wave conditions.

The reduction in dispersant effectiveness is partly due to the increase in viscosity, but is also due to the stability of the emulsion. Some recently developed dispersants have the capability to 'break' the emulsion (cause it to revert back to oil and water phases), particularly when the emulsion is freshly formed and not yet thoroughly stabilized. Some freshly formed have been dispersed. A double treatment of dispersant; the first stage at a low treatment rate, followed after some time by second treatment at a higher rate, has been found to be effective. However, as emulsified oil undergoes further weathering, the emulsion becomes more stable and dispersants become less effective. There is a need for prompt dispersant spraying, even though some modern dispersants can extend the "window of opportunity", compared to other products

A methodology for "mapping" of the dispersant efficiency as a function of the specific emulsion viscosity has to be established at SINTEF to obtain a documented foundation for the calculation of the probable "time window" for efficient dispersant application. Such studies have revealed that the emulsion viscosity limits for dispersibility might vary substantially between the different oils. This will have great influence on the calculation of the oils' actual "time window" for efficient dispersant use. Operationally, it will be important to determine the dispersibility of the oil and determine the "time windows" for application of dispersants under different weather situations. By combining the information from the dispersibility studies with the weathering prediction the operation window for the opportunity for the different oils can be established.

Crude oils have a wide range of chemical composition and chemical and physical properties. All crude oils are composed of mixtures of many different hydrocarbons, but the relative proportions of different hydrocarbon types and molecular weights vary over a very wide range. Some crude oils are 'light' and they contain a high proportion of volatile components, whilst others are 'heavy' and contain a high proportion of higher molecular weight hydrocarbons. Some crude oils contain a high proportion of wax, whilst others contain very little. All these variations in composition and properties cause different crude oils to 'weather' at different rates to different end-points. In addition, the rate of oil weathering is very dependant on sea state

The most accurate indication of oil weathering and the 'window of opportunity' for dispersant use can be obtained by conducting simulated weathering studies in the laboratory and testing dispersant performance in a range of laboratory test methods. Specific weathering studies have been conducted on some crude oils and refined oil products and examples of these are given in Section 4.

However, a huge number (certainly over 600 and probably near to 1000) of different and individual crude oils are regularly transported around the world to different destinations and many of these will be transported through EU waters. The identity of the oils transported changes with time as new oilfields are developed and old oilfields are depleted. It is most unlikely that all of these crude oils will be subjected to specific weathering studies and to testing with all of the dispersants that may be available to respond to spills of the crude oils

Estimates of the changes that are likely to occur in the physical properties of oils can be made by comparing the properties of the original oils with oils on which specific studies have been conducted. This method is used in the software tool that accompanies this Manual.

3.1.5 Dispersant performance in low salinity waters

Most dispersants are formulated to work well in open sea conditions with salinities of 30 psu (practical salinity units) or more. This is, in part, due to dispersants being developed in countries where their likely use is in locations such as the North Sea or the Atlantic or Pacific Oceans.

The non-ionic surfactants in oil spill dispersants are chemically sensitive to seawater salinity; the ethylene oxide chains are modified in orientation by the salt in sea water. Most - but not all - dispersants will not work very well in freshwater and the effectiveness of most dispersants decreases slightly down to 10 psu and then decreases sharply at lower salinities. This is unlikely to be important for many dispersant use scenarios because dispersants would not be used in lakes or rivers; the water volume is usually too small to allow for dilution to harmless concentrations of dispersed oil.

However, there are some circumstances when dispersion of spilled oil into low salinity water might be considered. The outflow from large rivers into the sea can cause large areas of low salinity water. There are relatively large low salinity areas of the sea associated with major rivers such as the Amazon and Mississippi. Melt-water from ice in the Arctic regions can float on top of the more dense seawater, producing a thin layer of low salinity water. And there are semi-enclosed seas with a high river water input, such as the Baltic Sea, where there are large areas of low salinity water.

Some dispersants, for example Dasic Freshwater dispersant, Disper ED, Inipol IPF and OD 4500, are available that have been specifically formulated to be effective in freshwater. They are also reasonably effective in seawater. Most countries do not have approval procedures that assess dispersant performance on spilled oils in freshwater, since their use would be rare. However, a specific test procedure was designed in France and includes, as with marine dispersants, an efficiency test, a toxicity test and a biodegradability test. For the efficiency test, the IFP dilution test method (NF.T.90-345) was chosen and the test conditions were modified by the iuse of freshwater and a different type of test oil. For the biodegradabilty test, the procedures are identical to those for marine dispersants. The toxicity test is carried out on a fresh water species, the zebra fish.

3.2 Oils on which dispersants should and should not be used

Although much emphasis has been concentrated on spills of crude oils, such as occurred at the *Torrey Canyon*, *Braer* and *Sea Empress* incidents, the most numerous oil spills that occur at sea are of much smaller quantities of refined oil products.

The most frequently spilled oils at sea are probably Marine Diesel Oil (MDO) and Marine Gas Oil (MGO). These distillate fuels are used by small boats and ships as fuel for their diesel engines. If an incident, such as a collision or sinking, happened to a small fishing boat a few tonnes of MGO or MDO will probably be spilled. Dispersants should **not** be used on spills of MGO or MDO because these oils are not persistent on the seas surface; they will evaporate to some degree and be naturally dispersed quite quickly because they do not form water-in-oil emulsions. Since they contain a high proportion of aromatic hydrocarbons, which are particularly toxic to marine life, dispersing these oils with dispersants could cause localized, but high concentrations of toxic oil compounds in the water column.

Many refined oil products are carried as cargo by the smaller classes of oil tankers. If these vessels are damaged their cargo may be spilled onto the sea. If gasoline (petrol) is spilled onto the sea it will rapidly and totally evaporate. In view of the possible fire and explosion risk, it is probably best to let this happen and not intervene. Dispersants should **not** be used as they would force toxic compounds such as benzene into the water column in large quantities.

The oils spilled from the *Tanio*, *Prestige* and *Erika* were very heavy fuels oils, residues from the oil refining process destined to be used as fuel for power generation stations. Dispersants would not be effective on this type of refined oil product; the viscosity of these oils is far too high for dispersants to be effective and the oil floats on the sea in layers that are many centimetres thick making effective dispersant treatment impossible. Dispersants should **not** be used on spills of very heavy fuel oils.

As described in Section 4, crude oils vary a great deal in their chemical composition and physical properties. A form of crude oil called “condensate” can resemble petrol or diesel fuel, being very light coloured and containing no ‘heavy’, or high molecular weight, chemical compounds. Most crude oils range from ‘light’, low viscosity, brown liquids to thick, sticky, black fluids with the consistency of molasses. The rate at which they ‘weather’ - lose the more volatile compounds by evaporation and incorporate water to form emulsions - varies over an enormous range. Dispersants can generally be used on most crude oils, but there are exceptions; most “condensates” will not form emulsions and are therefore not persistent, so dispersants are not generally used on spills of “condensates”. Some crude oils have an extremely high viscosity, or are solid at typical sea temperatures due to having a very high Pour Point. It would be pointless to apply dispersants top these crude oils.

Table 4 contains a summary of the oils on which dispersants should and should not be used, categorized by the type of vessel involved in an incident.

Incident involving	Spilled oil	Dispersant use effective or appropriate ?
Fishing vessel	Marine Diesel Oil Marine Gas Oil	No
Small cargo ship	Medium Fuel Oil	Yes
Medium cargo ship	Medium Fuel Oil	Yes
Product tanker	Medium / Heavy Fuel Oil	Yes
Product tanker	Gasoline cargo	No
Product tanker	Jet fuel cargo	No
Product tanker	Diesel cargo Vegetable oil	No No
Product tanker	HFO for power use	No
Large cargo ship	Heavy Fuel Oil	Possibly
Oil tanker	Heavy Fuel Oil	Possibly
Oil tanker	Condensate	Probably No
Oil tanker	Crude oil cargo	Yes – for some time

Table 4. Vessel incidents, oils likely to be spilled and the appropriateness of dispersants as an oil spill response method

4. DATA FROM DISPERSANT EFFECTIVENESS STUDIES

4.1 Data from oil weathering

SINTEF use a standardized methodology to simulate the weathering processes that occur on sea. This methodology uses distillation to various end-point temperatures to simulate the evaporation of the more volatile components from oil spilled oil at sea and a laboratory method to simulate the water incorporation process that forms water-in-oil emulsions. These two simulated weathering processes are used to create a matrix of oil samples (Figure 4.) on which specific testing is conducted.

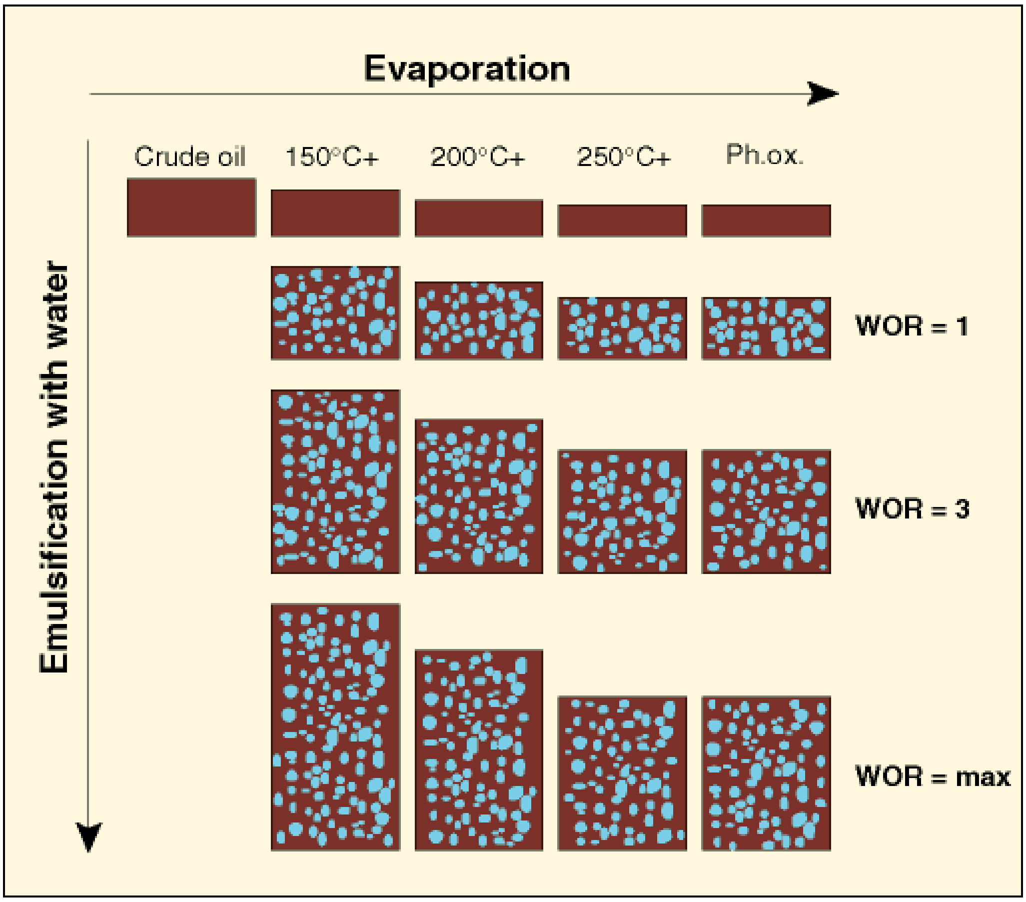


Figure 4. Matrix of samples created by SINTEF bench-scale, step-wise oil weathering study

The physical properties (viscosity at various temperatures, density etc.) of these samples are determined and assessed. And used as input to the SINTEF Oil Weathering Model (Figure 5.)

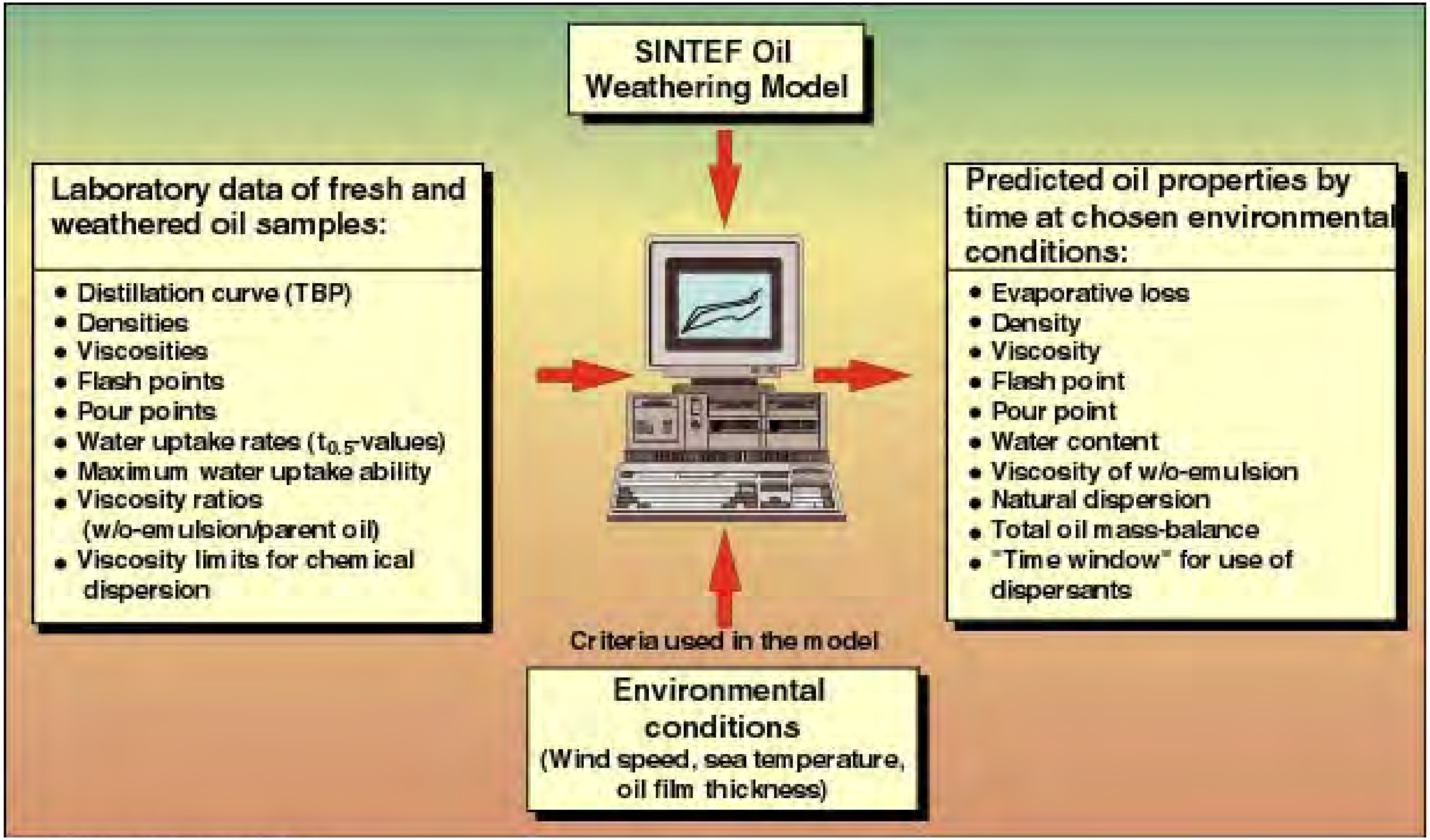


Figure 5. Inputs and outputs of the SINTEF Oil Weathering Model

4.2 Dispersant effectiveness

The phrase “dispersant effectiveness” has come to mean several different things depending on the context in which the phrase is used.

Most simply, referring to the ‘effectiveness’ of a dispersant when used on spilled oil at sea is a non-quantitative indication of the degree to which a dispersant appears to be working, i.e. causing oil to disperse. If spilled oil on the sea is sprayed with dispersant and then a brown plume of dispersed oil is easily visible in the water soon after a wave passes through the dispersant-treated oil, it is reasonable to say that the dispersant appears to be working well, is ‘effective’ or even that the dispersant appears to have a ‘high effectiveness’.

4.2.1 Dispersant effectiveness in laboratory tests

“Dispersant effectiveness” has a much more specific meaning when used to describe the results obtained from a specific laboratory test method. Dispersant effectiveness in this case is a numerical percentage value, where 0% is equivalent to no dispersion of oil at all and 100% is equivalent to total dispersion of all of the oil. A percentage value of dispersant effectiveness in this context is only strictly applicable to the test method, test oil and under the conditions (temperature, salinity, treatment rate etc.) it was obtained.

Many different dispersant test methods have been developed around the world. In principle they are all similar; dispersant is added to test oil on seawater in a particular apparatus and the oil and water are mixed by some agitation method. After a specified period, the mixing may be stopped and a sample of the water containing dispersed oil is taken and analysed for oil content. The different methods differ in many details; the intensity of agitation and the relative volumes of oil and water are two of the most obvious. Different test methods produce different numerical results when the same dispersants and same oils are tested under otherwise identical conditions. Some tests are higher-energy tests than others.

In Norway, SINTEF use the IFP test as a relatively low-energy test method and the MNS test as a higher-energy test method for measuring dispersant effectiveness. Schematic diagrams of the two methods are given in Figure 6.

The dispersant effectiveness result obtained by any test method depends on many factors, but the energy level is the most dominant. The percentage effectiveness results obtained from the higher-energy MNS test will generally be higher than those from the lower-energy IFP test if the same dispersants, treatment rate test oil, temperature, salinity etc. are used. The higher energy test simulates - to a partial degree - a rougher sea than the lower-energy IFP test, but no laboratory test method is an adequate simulation of all the different processes that occur at sea.

An accurate percentage “dispersant effectiveness” value is easy to obtain from a laboratory test. Many variables can be altered in a controlled manner and many tests can be completed reasonably quickly.

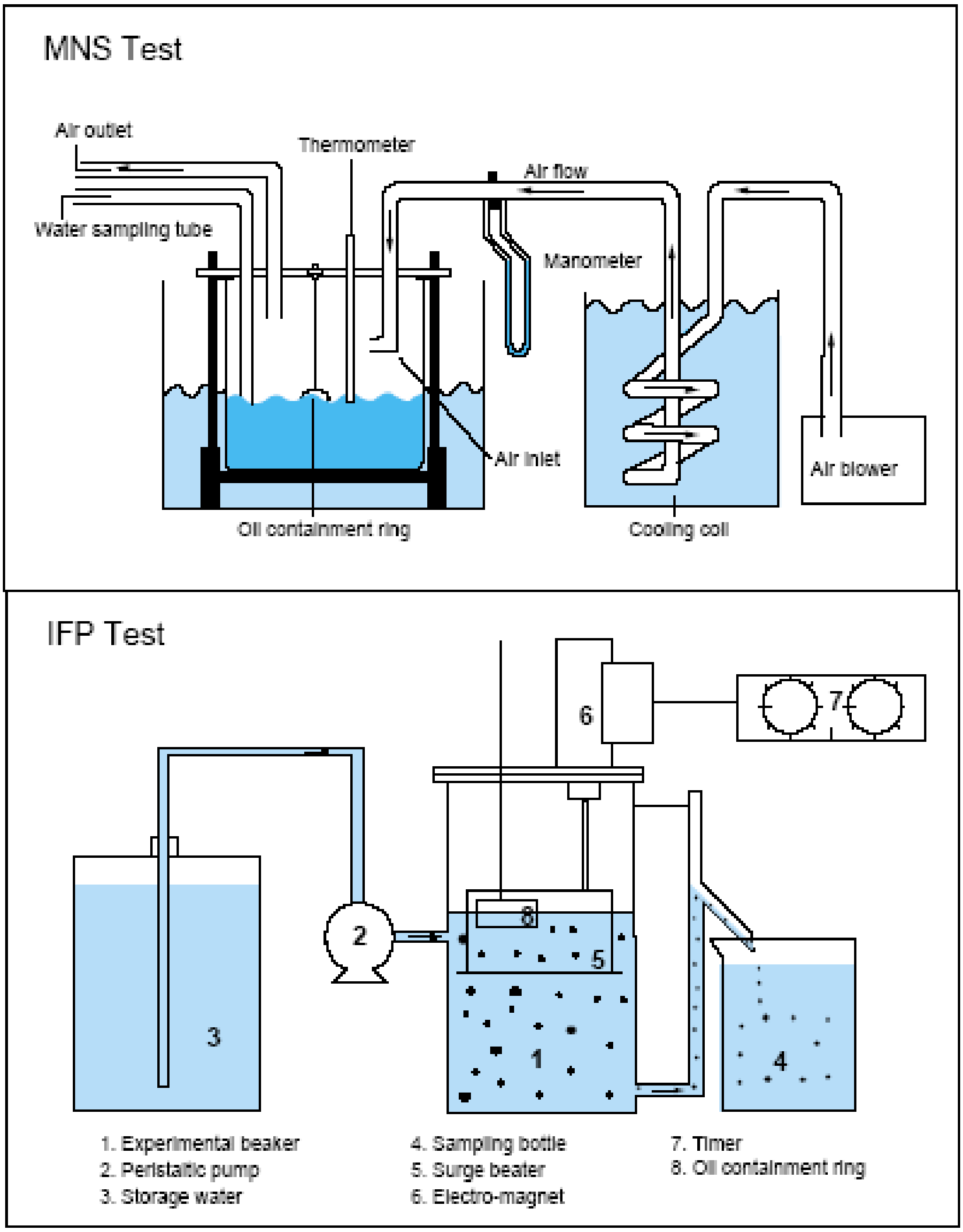


Figure 6. The MNS and IFP dispersant test methods

Laboratory tests are closed, or limited dilution, systems where the total quantities of test oil and water are known. Standardised mixing conditions can be applied for the specified time and then a sample of the water containing dispersed oil can be removed and analysed for oil content. It is then simple to calculate the proportion, or percentage, of the original oil that has been dispersed. However, different test methods produce different effectiveness values (percentages) even when the same dispersant, treatment rate and test oil are used. This is because the mixing conditions are different. For example, in the WSL method this effectiveness percentage represents the amount of oil dispersed in the test flask after 30 seconds standing, while in the IFP method, it represents a comparison between the dispersed oil flushed out of the test tank during the test and the quantity of a pure soluble compound that would have been flushed out in the same condition.

4.2.2 Measuring dispersant effectiveness at sea

Unfortunately, the simple procedure used to determine dispersant effectiveness in laboratory tests cannot be duplicated at sea. The sea is effectively an open system - not in a closed container - and dispersed oil is rapidly diluted to very low concentrations in a vast quantity of water. It is sometimes possible to know the exact amount of oil that has been spilled, but it is currently not possible to accurately measure the amount of oil that remains on the surface at any particular time, or to accurately measure the amount of oil that has been dispersed. It is therefore not possible to calculate the percentage of the original oil that has been dispersed and express this as a percentage "dispersant effectiveness" value in the same way as can be so easily done in laboratory tests.

The best method currently available for estimating how effective dispersant use at sea is has been to use Ultra-Violet Fluorometry (UVF). UVF detects the aromatic components in an oil. A submerged 'fish' is towed at several depths from 1 to 10 metres below an oil slick with the oil being pumped from this depth to a UVF instrument in a boat. The UVF instrument will detect the dispersed oil droplets and the partially water-soluble aromatic compounds that are released from the oil. The instrument needs to be calibrated for different types of oil and the calibration changes with the dilution of the dispersed oil as the oil 'weathers'. The UVF instrument readings can be 'back-calibrated' by taking water samples for subsequent analysis in a laboratory. This will enable the relative concentration reading to be converted into absolute concentration readings such as ppm (parts per million) of dispersed oil in water.

UVF readings taken below an oil slick before dispersant is used will record the low dispersed oil concentrations in water that are produced by natural dispersion. Figure 7 shows an example of such measurements made at the NOFO exercise in 1995.

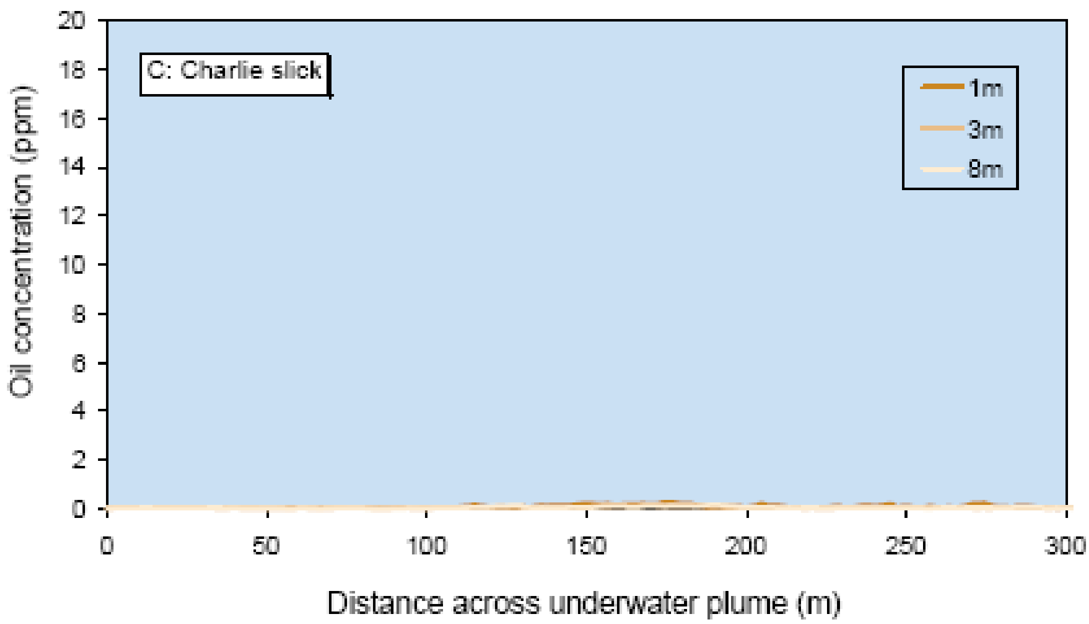


Figure 7. Dispersed oil in water concentrations underneath an untreated oil slick

Figure 8 shows the dispersed oil in water concentrations underneath a slick of the same oil (Troll crude) approximately 30 minutes after the slick was sprayed with dispersant from a helicopter.

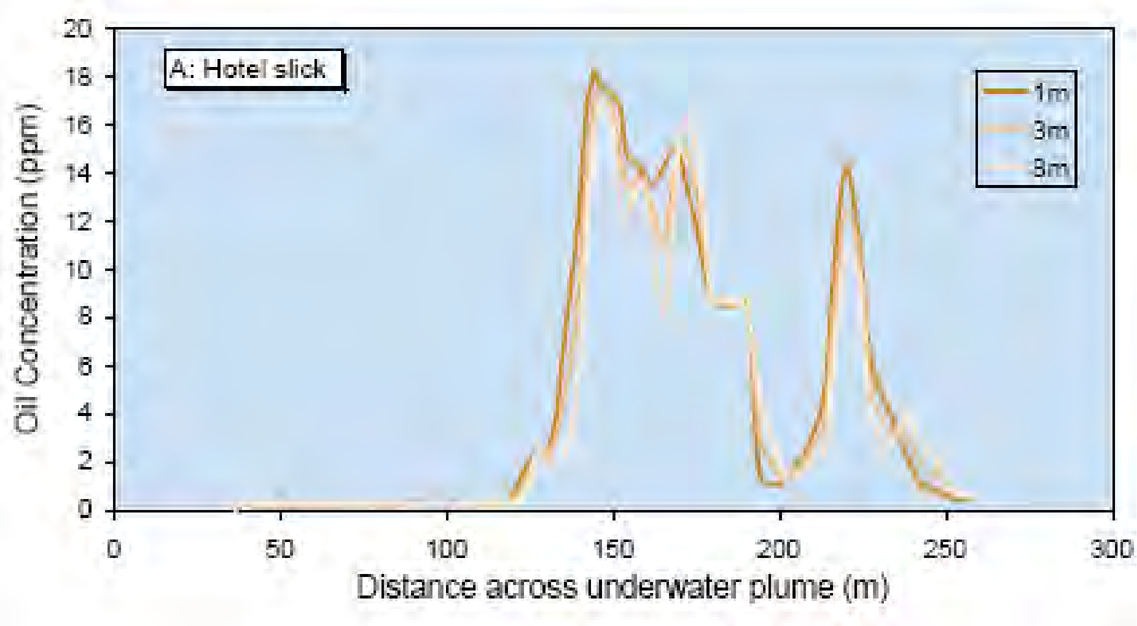


Figure 8. Dispersed oil concentrations underneath an oil slick sprayed with dispersant

There is an obvious increase in the dispersed oil in water concentration below the dispersant-treated slick, compared to that underneath the untreated slick. This is very indicative of a high level of 'dispersant effectiveness', but the oil concentration values along a line under the slick cannot be converted into a calculation of the total volume of oil dispersed from the slick. This is because the oil concentrations can only be measured along a 'transect' - a line across or along the slick - at a few water depths. In order to accurately calculate the total volume of oil dispersed at any time it would be necessary to measure the dispersed oil concentration at all points below the slick and this is not feasible with today's technology.

4.2.3 Dispersant effectiveness in the laboratory and at sea

It is important not to 'mistranslate' the dispersant effectiveness value obtained in a laboratory test method directly into the likely dispersant performance at sea. A dispersant and test oil combination that produces a 60% result in the IFP test method (for example) will not cause 60% of the volume of the same oil to be dispersed into sea, while leaving 40% of the oil volume on the sea surface.

The relationship between dispersant effectiveness results obtained in a particular test methods and the performance of dispersant used at sea is not a direct, absolute correlation, but is a relative indication. If dispersant A produces an IFP dispersant effectiveness test result of 60% and dispersant B produces a result of only 30% with the same test oil, it is likely that dispersant A will perform 'better' at sea. This 'better' performance is most likely to be apparent as more rapid dispersion of the oil, rather than 40% of oil being left on the surface when sprayed with dispersant A and 70% being left on the surface if sprayed with dispersant B.

Experience of dispersant performance gained at several sea-trials and at actual incidents seems to show that the division in dispersant performance at sea is more sharply divided into (i) almost totally effective, i.e. near total dispersion, or (ii) almost totally ineffective, i.e. very little dispersion, than the smooth continuum from 0% to 100% dispersant effectiveness implied by the dispersant effectiveness results obtained in laboratory tests. If an oil is going to disperse at sea after being sprayed with dispersant it tends to do so quite quickly, within 30 minutes or an hour. If the oil is not going to disperse after being sprayed with dispersant, then it tends not to do so even a long time after dispersant spraying. Because of the difficulty and complexity in assessing dispersant effectiveness at sea it is not possible to be absolutely definitive about this effect, but it fits in with the visual observations that dispersants are washed off of high-viscosity oils and therefore do not disperse.

A similar transition from a high level of dispersant effectiveness to a much lower effectiveness with higher viscosity oils has been observed in many laboratory studies. This gave rise to the concept of a 'limiting oil viscosity' for dispersion; oil with a viscosity below a limiting value could be dispersed and oils with a viscosity above this value could not. In the past, a limiting viscosity of 2,000 cP (centiPoise) was suggested. Subsequent studies have revealed that this limiting oil viscosity for dispersion should not be applied to emulsion viscosity because oils in an early stage of emulsification can be 'broken' back to oil and water by the demulsifying effect of many dispersants. Further studies have shown that some dispersants can disperse higher viscosity oils than other dispersants.

SINTEF and other organisations such as AEA Technology plc in the UK and CEDRE in France have studied the dispersibility of many different oils in various states of simulated weathering using different laboratory test methods. This procedure produces a series of weathered oils and emulsion samples of increasing viscosity, all derived from a single crude oil.

Dispersant testing on these oils and emulsions using the IFP and MNS test methods produces graphs such as that shown in Figure 9.

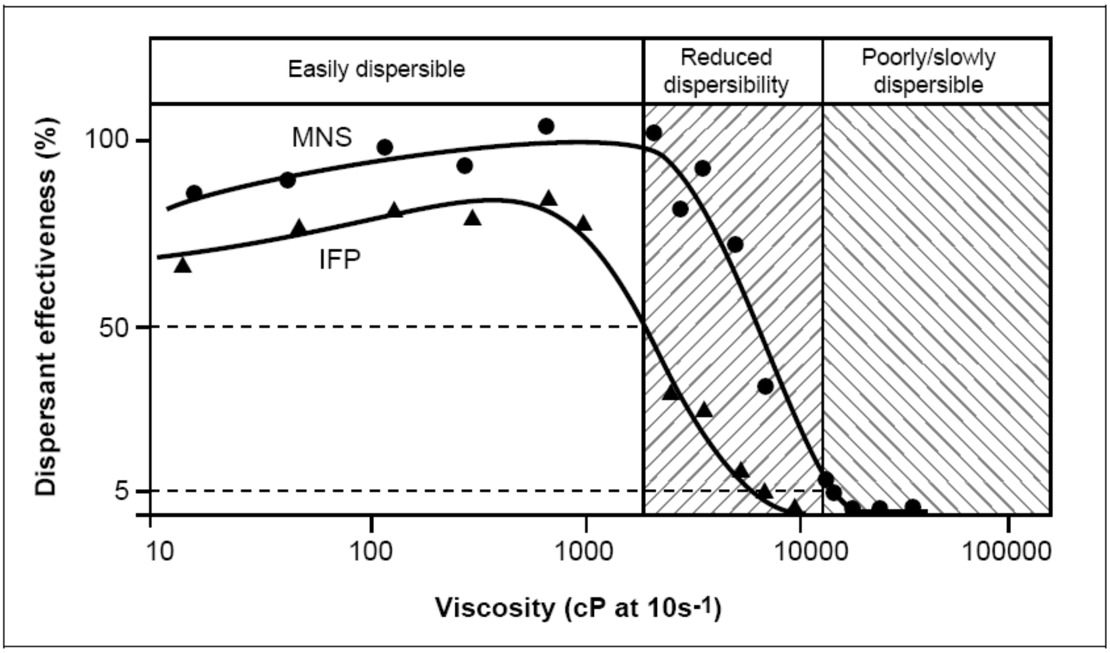


Figure 9. Dispersant effectiveness results obtained on a series of weathered oils and emulsions

The low-viscosity weathered samples are easily dispersed and produce high dispersant effectiveness results in both the MNS and IFP methods. The more highly weathered and higher-viscosity samples are much less dispersible and produce very low results in both dispersant test methods. There is an intermediate zone where results from the relatively low-energy IFP test method are reduced with increasing sample viscosity, before a similar effect occurs in the results from the higher-energy MNS test method.

On the basis of their experience and results from several sea trials, SINTEF have divided the dispersant effectiveness into three categories; “Easily dispersible”, of “Reduced dispersibility” and “Poorly / slowly dispersible”, based on the results from the IFP and MNS test methods. The numerical limits of the results from the two different test methods that define these categories are shown in Figure 10.

Chemical dispersible	if the effectiveness is higher than 50% with the IFP-test and 70-80% with the MNS-test.
Reduced dispersibility	where the IFP-values drops below 50% to the viscosity where the MNS shows 5% effectiveness.
Poorly / slowly dispersible	if the MNS-value is showing less than 5% effectiveness.

Figure 10. SINTEF categories of dispersibility

Other organizations have adopted different limits based on different dispersant test methods. AEA Technology proposed in 1998 that results above 15% in the WSL (Warren Spring Laboratory) test method should equated with an oil being ‘dispersible’ with the implication that a figure below this value would equate to an oil being ‘not dispersible’. In its weathering studies Cedre used the IFP test with the following limits: above 50% is “easily dispersible”, between 50% and 20% is of “reduced dispersibility” and below 20% is considered to be “not dispersible”. Experiments conducted at sea in 2003 indicated that for Heavy Fuels Oils (HFOs) in relatively calm seas this was not the case and that a higher WSL result - perhaps 60% - would be a more appropriate indicator.

The SINTEF categories relate results obtained in the IFP low-energy test and the MNS high-energy test with the likely performance of dispersants at sea. Experiments conducted at sea indicate that the laboratory derived dispersibility boundaries are in fairly good agreement with the field observations. The laboratory test methods produce data that represents, however, only a "snapshot" of the dynamic and time-dependent dispersion process which often takes place at sea.

In particular, the SINTEF dispersibility categories do not, in themselves, take account of sea-state. Although it is known that simple laboratory tests such as the IFP and MNS test methods cannot accurately simulate all the mixing and dilution processes that happen at sea, there is a belief that the lower-energy IFP test might be more indicative of dispersant performance in a calmer sea, while the high-energy MNS test might be more indicative of dispersant performance in a rougher sea. It might therefore be necessary to adjust the category boundaries to take account of the sea-state effect with the dispersant effectiveness results ‘drop-off’ with viscosity of the IFP test method being more relevant in calmer seas, while the effectiveness ‘drop-off’ with viscosity in the MNS test method being more relevant for rougher seas.

Several attempts have been made to resolve these ambiguities and refine the categorization of dispersibility, such as the study conducted by SINTEF, AEA Technology and CEDRE for OSRL in 1997. However, all these studies have been based only on laboratory studies without the necessary correlations conducted at sea. The current situation is that the SINTEF categorization of dispersibility based on the IFP and MNS remains the most sophisticated correlation available. It is based on a limited correlation with measurements of dispersion made at sea, simply because only a few sea-trails have been conducted in recent years.

4.2.4 Operational use of SINTEF categories of dispersibility

The three categories of dispersibility “Easily dispersed”, “Reduced dispersibility” and “Poor / slowly dispersible”, are determined by SINTEF using the different laboratory test methods. SINTEF have conducted a great deal of work on this topic and have found that different crude oils have different viscosity limits that describe these categories as in the diagram below (Figure 11).

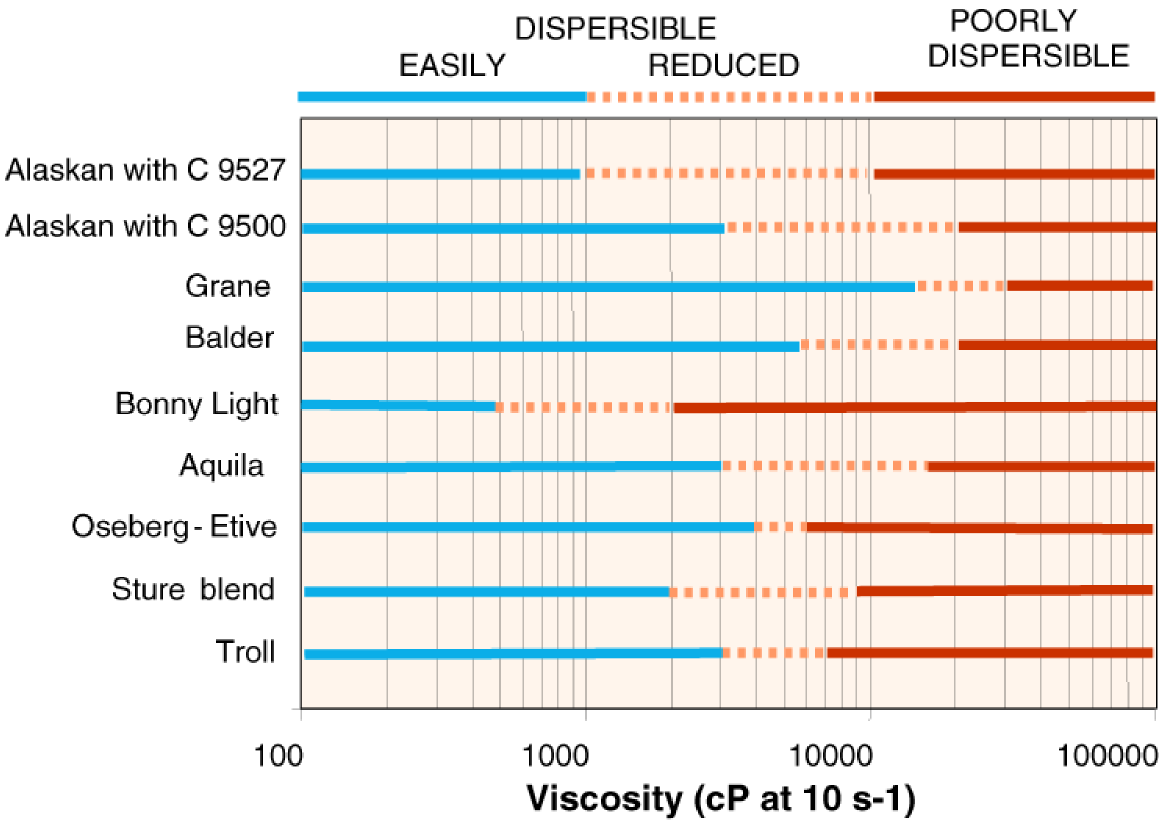


Figure 11. Examples of different categories of dispersibility for different oils

The main purpose of these categories is for estimating the “time window of dispersant use” when used in conjunction with computer modelling of the different oil weathering processes. The processes such as evaporation of the more volatile oil components and incorporation of water droplets to form emulsified oil take place at rates that depend on the prevailing environmental conditions of temperature and wind speed. Evaporation takes place more quickly at higher temperatures and emulsification takes place more quickly in rougher seas at higher wind speeds. The viscosity of the emulsified oil (and therefore the dispersibility of the oil) changes at a rate that depends on the prevailing conditions.

The diagram below (Figure 12) illustrates this effect. The viscosity of Troll crude oil spilled onto the sea with a temperature of 13ºC increases much more quickly at a wind speed of 15 m/s (approximately 30 knots) than it does at a wind speed of 2 m/s (approximately 4 knots).

The viscosity limits that define the dispersibility categories for weathered Troll crude oil have been determined in the laboratory to be; "Easily dispersible" up to 3000 cP, "Reduced dispersibility" between 3000 cP and 7000 cP and Poorly / slowly dispersible above 7000 cP.

The first limit (the dividing line between easily dispersible and reduced dispersibility) of 3000 cP occurs after only 2 hours in a 15 m/s wind, but after nearly 2 days in a 2 m/s wind. The second limit (between reduced dispersibility and poorly / slowly dispersible) of 7000 cP occurs after 1 day in a 15 m/s wind and more than 5 days in a 2 m/s wind.

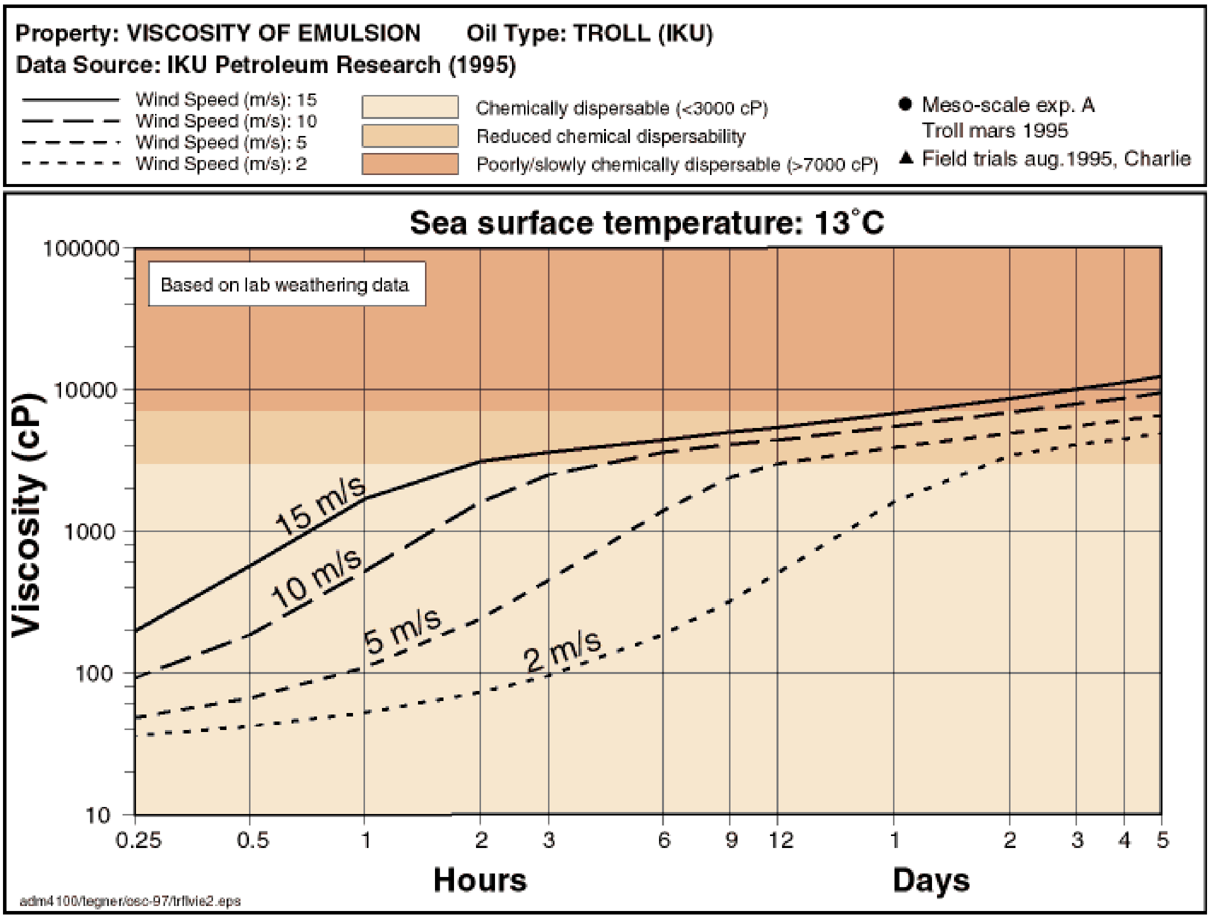


Figure 12. Evolution of emulsion viscosity and dispersibility category for Troll crude oil

If the above information is available for a particular crude oil and dispersant combination the limits can be broadly interpreted in the following way for operational use of dispersants:

Easily dispersible

Dispersant spraying the oil in practically any sea condition or wind speed will lead to relatively quick and almost total dispersion of the oil, provided that the dispersant is sprayed accurately onto the spilled oil at the recommended treatment rate. The oil will be dispersed more rapidly in rough seas and high wind speeds, but will also be rapidly dispersed in calmer seas at lower wind speeds, down to 5 knots and is even likely to disperse in very calm conditions.

Reduced dispersibility

This is the main dividing line between “the oil will disperse” and “the oil will not disperse”.

When the spilled oil is in this viscosity range it will be easily dispersed in sea conditions caused by wind speeds above 12 to 14 knots, but be more slowly dispersed in calmer seas, particularly below 7 or 8 knots when cresting waves are not present.

A high level of confidence in dispersing the oil would be reasonable above a wind speed of 12 or 14 knots (6 to 7 m/s) and there is also a reasonable probability of success at lower wind speeds of 5 knots or less.

Poorly / slowly dispersible

Dispersant spraying is likely to be ineffective in any sea state even at the maximum wind speed of above 30 knots, above which dispersant spraying would be ineffective because the oil would be submerged for much of the time.

5. OPERATIONAL USE OF DISPERSANTS

5.1 Storage of oil spill dispersants

Because dispersants are only used in unforeseen emergencies when oil spills occur, and large oil spills are very rare events, they are often purchased long before they are used. Dispersants can be kept in storage for a very long time, provided that they are stored in the correct conditions. The surfactants and solvents in dispersants are chemically stable; they will not undergo decomposition or other changes, provided that they are stored properly.

Oil spill dispersants should be stored in the sealed containers (drums or IBC containers) in which they were supplied by the manufacturers. These containers should be protected from extremes of temperature and should therefore be stored under cover or inside buildings such as warehouses. Steel drums stored outside for a very long time will eventually rust through from the outside and will then leak.

Transferring dispersants into bulk storage in tanks carries the risk of mixing different brands or Types of dispersant. Brands of even the same dispersant Type should not be mixed because the individual formulations were optimized for high effectiveness by blending different surfactants and solvents; mixing two brands together will possibly reduce the effectiveness of the mixture to below that of the individual brands.

Bulk storage is also to be avoided because large tanks often have “breather tubes”, open to the air, to allow for expansion and contraction in the volume of the tank contents caused by fluctuations in temperature. Some of the solvents in some dispersant may evaporate over a long period of time. Additionally, the prolonged exposure to air via the “breather tube” may cause oxidation of the fatty acid (vegetable oil) part of the surfactants in the dispersant, leading to the formation of sticky, gum-like residues. Particles of ‘gum’ formed in this way will block spray nozzles. Storage on board ships is often in dedicated dispersant storage tanks. Despite care being taken, experience has shown that contamination of the dispersant with seawater or other materials often occurs.

Mixing of different types of dispersant must be avoided. Mixing of a “Conventional” (or “Hydrocarbon-base”, “UK Type 1”) dispersant with a “Concentrate” (“Water-dilutable or “UK Type 2”or UK Type 3) dispersant can cause the mixture to produce a viscous gel. This will render the mixture impossible to spray.

To check whether there have been any problems during storage of dispersants in stockpiles, countries such as France and Norway check the properties of dispersants every 3 years and in the UK the dispersant is checked after 10 years if stored in the original container and every 5 years after that.

5.2 Transport of oil spill dispersants prior to use

Dispersants have a Flash Point above 60ºC. They do not generally have to be labelled as Hazardous or Inflammable materials for transport, although some labelling, depending on specific ingredients, may be required. The Material Safety Data Sheets (MSDS) for individual dispersants should be consulted for further details.

5.3 Using oil spill dispersants

Oil spill dispersants are most commonly used by spraying them onto spilled oil on the sea surface. Oil spill dispersants need to be applied to spilled oil in a manner that allows the surfactants within the dispersants to soak into the oil and then allow wave action to disperse the dispersant-treated oil. Since the spilled oil is on the sea surface in the form of an oil slick, the most obvious way is to spray the dispersant onto the oil. Any other approach would involve containing or corralling the oil, adding dispersant and then releasing the dispersant-treated oil back onto the sea surface where it would be dispersed by wave action.

- **All three types of dispersant**:
  - "Conventional" ("Hydrocarbon-base" or "UK Type 1") dispersants;
  - "Concentrate", both:
    a. those sprayed with water dilution; "Water-dilutable Concentrate" or "UK Type 2" dispersants
    b. those sprayed without dilution, or neat; "Concentrate" or "UK Type 3" dispersants

  can be sprayed from boats and ships fitted with the appropriate spraying equipment.

- **Only** "Concentrate" sprayed without dilution ("UK Type 3") dispersants should be sprayed from aircraft (helicopters and fixed-wing).

Since many modern dispersants are of the "concentrate type" and most are also UK Type 2/3, most – but not all - dispersants can be sprayed from both ships and aircraft, but it is essential that the correct spraying equipment is used in order to achieve the recommended treatment rate.

5.3.1 Recommended treatment rates for dispersants

These recommended treatment rates of different types of dispersant (Table 5) have been derived from studies in the laboratory where known amounts of dispersant have been added to known amounts of oil.

Generation	Description	UK Type	Sprayed from	Recommended treatment rate
Second	"Conventional" or "Hydrocarbon-base"	UK Type 1	Ships, boats, onshore	**High treatment rate** 30 - 50% dispersant as volume of spilled oil or **1 part dispersant to 2 to 3 parts oil**
Third	"Concentrate" or "Water-dilutable concentrate"	UK Type 2	Ships and boats	**10% solution of dispersant in seawater to** **2 to 3 parts oil** Equivalent to 1 part dispersant to 20 to 30 parts oil
	"Concentrate"	UK Type 3	Aircraft, ships and boats	**Low treatment rate** 3 to 5% dispersant as volume of spilled oil or **1 part dispersant to** **20 to 30 parts oil**

Table 5. Recommended dispersant treatment rates

5.3.2 Considerations of dispersant treatment rate applied at sea

Spilled oil floats as oil slicks of highly variable oil thickness and the localized oil layer thickness varies enormously over short distances. A commonly used assumption is that the average oil layer thickness in an oil slick is 0.1 mm. It must be appreciated that this is an average of a very wide range.

Dispersant sprayed from ships or aircraft should be deposited onto the spilled oil in the correct quantity so that the recommended treatment rate (for the particular dispersant Type) is achieved. Dispersant is sprayed from nozzles mounted on spray arms that are several metres wide. The nozzles are normally arranged to provide an even deposition of dispersant onto the spilled oil, so that the amount of dispersant is deposited evenly over a unit area (for example, each square metre) of spilled oil.

An average oil layer thickness of 0.1 mm is equivalent to 100 cm^3 of spilled oil per square metre, or 100 m^3/km^2. The required deposition rate of dispersant on this average spilled oil thickness will be:

Dispersant	UK Type	Sprayed from	Required deposition rate of dispersant on a 0.1 mm thick oil layer
"Conventional" or "Hydrocarbon-base"	UK Type 1	Ships, boats, onshore	20 to 30 m^3/km^2
"Concentrate" or "Water-dilutable Concentrate"	UK Type 2	Ships and boats	20 to 30 m^3/km^2 of a 10% solution of dispersant in seawater
"Concentrate"	UK Type 3	Aircraft, ships and boats	2 to 3 m^3/km^2

Table 6. Deposition rate of dispersant on a 0.1 mm thick oil layer

The dispersant deposition rate is determined by the dispersant pump flow rate and the speed of the spraying vessel.

5.3.3 Variation of oil layer thickness within an oil slick

The great variation in spilled oil layer thickness has implications for dispersant spraying. One of the obvious problems in determining the amount of dispersant to be sprayed onto slicks of spilled oil is the lack of any simple means to accurately determine the thickness of the spilled oil layer.

Low viscosity crude oils rapidly spread out to form oil layers that are quite thin, but there is a very wide range of oil thickness in a typical oil slick. A typical slick of freshly spilled crude oil will contain large areas of sheen that are approximately 0.04 to 0.3 microns thick and much smaller patches of oil that are more them 200 microns thick. The areas of thicker oil can rapidly emulsify and this will increase the layer thickness to nearly a millimetre (while still containing the same amount of oil). Emulsified oil concentrates in 'windrows' (caused by circulation cells within the water caused by the wind) and the oil in these windrows can be several millimetres thick. Additionally, oils of different viscosity spread out to form layers of different average thickness; very high viscosity oils like the heavy fuel oils spilled from the *Erika* and *Prestige* form patches that are many centimetres thick, up to 50 cm in some cases.

It is currently not possible to accurately measure the thickness of the oil layer within different areas of an oil slick by visual observation or any remote sensing technique, but very thin layers of spilled oil can be distinguished from thicker oil layers by simple visual observation.

The Bonn Agreement has recently adopted the Bonn Agreement Oil Appearance Code (BAOAC) (Table 7) to replace the previous Bonn Agreement Colour Code.

CODE	Description	Layer thickness interval (µm)	litres per km^2
1	Sheen (silvery/grey)	0.04 - 0.30	40 - 300
2	Rainbow	0.30 – 5.0	300 – 5000
3	Metallic	5.0 - 50	5000 – 50,000
4	Discontinuous true oil colour	50 – 200	50,000 – 200,000
5	Continuous true oil colour	More than 200	More than 200,000

Table 7. The Bonn Agreement Oil Appearance Code (BAOAC)

The thickness of the oil layer in an oil slick will vary from less than 1 micron (one thousandth of a millimetre) in the areas of sheen, to several millimetres or – in the case of higher viscosity oils – several centimetres or more. These variations in thickness can be very localized; small patches of thicker oil (that are one millimetre or much more in thickness) may be surrounded by areas of much thinner oil.

Very thin layers of spilled oil should **not** be sprayed with dispersant. Sheen (classified as "Silvery / Grey" in the BAOAC) has a thickness of 0.04 - 0.3 μm. Such sheen will be dispersed naturally and rapidly by wave action. Spraying sheen with dispersant from equipment designed to spray a 0.1 mm thick layer will result in treatment rates much higher than the recommended rates by a factor of approximately 300 to 2500. The sheen will be dispersed, but the amount of dispersant used will be far greater than the amount of oil dispersed. This would be an extremely wasteful use of dispersant.

Spraying the ‘metallic’ looking area of an oil slick with dispersant from spraying gear designed to treat an oil layer 0.1 mm thick will inevitable cause dispersant over-treatment by a factor of from 2 to 20 times. Dispersant spraying should be concentrated on the thickest areas of an oil slick; Codes 4 and 5 in the BAOAC. Spraying areas of oil designated as BAOAC Code 4 - Discontinuous true oil colour - with dispersant will, on average deliver approximately the recommended treatment rate of dispersant. Spraying areas of oil designated as BAOAC Code 5 - Continuous true oil colour and more than 200 µm, that is 0.2 mm thick - with dispersant will, on average deliver approximately half the recommended treatment rate of dispersant, but will be much less than this for thicker oil layers. Repeated spraying of these areas will be required to achieve the recommended treatment rate of dispersant.

Any dispersant spraying operation of spilled oil at sea will result in localized over-dosing and under-dosing; this is inevitable because of the variable and unknown variations in oil layer thickness. Over-dosing is a waste of dispersant and under-dosing will lead to partial dispersion or, perhaps, no dispersion of the sprayed oil.

5.4 Spraying oil spill dispersants - general considerations

Dispersants can be sprayed from any 'platform' - surface vessel or aircraft - on which a suitable spraying system can be mounted. The main principles for any dispersant treatment strategy are:

- Spray the spilled oil with dispersant as soon as possible after it has been spilled.
- Spray dispersant on the thickest patches of oil and do not spray dispersant on sheen.
- Try to accurately target the dispersant spraying onto the thickest patches at the recommended treatment rate.

It is not easy to fulfil all of these requirements.

For an effective treatment, the dispersant must be applied on the oil:
- In the correct quantity to limit dispersant wastage;
- By means of a spray to obtain a good dispersant / oil contact.

This result can be attained only by using specialized equipment which has been previously inspected and well maintained.

Any dispersant spraying system will consist of:

(i) A tank to hold the dispersant to be sprayed.
(ii) A pump to transfer the dispersant to the:
(iii) Spray arms, on which are mounted the
(iv) Nozzles which convert the stream of dispersant into droplets of the required size distribution.

The pump rate needs to deliver the required amount of dispersant to the nozzles at a pressure appropriate to the nozzle design. Too high a pressure can result in a fine mist of dispersant being produced. The small dispersant droplets in this fine mist will be blown 'off-target' by any wind. If too low a pressure is generated at the nozzles, the dispersant will not come out as a spray, but will dribble out as discrete streams of dispersant.

The best dispersant droplet size for dispersant spraying is droplets with diameters between 400 microns (0.4 mm) and 700 microns (0.7 mm). This is very similar to fine rain. Too fine a spray will be blown off-target, too coarse a spray will penetrate through the spilled oil and be lost to the water underneath the oil slick.

The above factors should be incorporated into a well designed dispersant spraying system by the manufacturer.

The main characteristics of any dispersant spraying system are:

(i) The payload - the amount of dispersant that can be carried.
(ii) The swath width - the width over which the spray system can deliver dispersant to the spilled oil at the recommended treatment rate.
(iii) The encounter rate - the speed of the platform multiplied by the swath width to produce an area / time (m^2 / hour, for example).

5.5 Spraying dispersants from boats and ships

5.5.1 Development of dispersant spraying systems for vessels

Equipment for spraying dispersants from small ships was developed by Warren Spring Laboratory (WSL) and manufactured by Biggs Wall Fabricators Ltd shortly after the *Torrey Canyon* incident. The equipment became the basis of UK response to oil spills and was widely used throughout the world.

At that time, the second generation or UK Type 1 “Hydrocarbon-base” or “Conventional” dispersants were the only type available. The recommended treatment rate was 1 part dispersant to 2 to 3 parts of spilled oil. The original WSL “Offshore” dispersant spray set consisted of two spray arms, each 8 metres long with 3 spray nozzles. The dispersant application rate was fixed at 20 gallons / minute (100 l / min) and the effective swath width (length of spray arms plus width of ship) was said to be 20 metres. The spraying took place at 5 to 10 knots and an ‘agitation board’ (several wooden pallets wired together) was towed behind the ship to add extra mixing to the dispersant-treated oil. This system could apply 6 tonnes of dispersant in an hour, in theory treating between 12 and 18 tonnes of oil.

A smaller, but similar “Onshore” version of the WSL spay set was developed for small boats with a pump rate of 7 gallons / minute (35 l / min) over a swath width of 12 metres. This system could apply just over 2 tonnes of dispersant in an hour, in theory treating just 4 to 6 tonnes of oil.

When UK Type 2, or ‘”Water-dilutable or concentrate”’ dispersants were introduced the original spray system design was modified. Type 2 concentrate dispersants are as effective as Type 1 dispersants when used as a 1:9 dispersant: seawater mixture. The pumps were changed so that a mixture of 1 part of dispersant and 9 parts of seawater could be pumped at the same rate of 20 gallons / minute (100 l / min). The dispersant is added to the seawater flow using and eductor and a second pump is not needed. The boats and ships could spray the UK Type 2 dispersant / water mixture for 10 times longer before they had to return to port, compared to using UK Type 1 dispersants. They could therefore treat 10 times the quantity of spilled oil as was possible with the Type 1 dispersants. However, the ‘encounter rate’ - based on an assumed average oil layer of 0.1 mm - was still very low at approximately 15 tonnes of oil / hour for the “Offshore” system and 5 tonnes of oil / hour for the “Onshore” system.

Dispersant spray systems for ships and boats continue to be made by several manufacturers.

Some spray systems for vessels are now available that use “Concentrate”, UK Type 3 dispersants. These systems spray dispersant at the much lower recommended treatment rates for this type of dispersant. The pump flow-rate is much lower than for the ”Water-dilutable or concentrate”’, UK Type 2 dispersants and the nozzles that are used dispense the “Concentrate”, UK Type 3 dispersants with the correct droplet size distribution.

5.5.2 Operational guidelines for spraying dispersants from vessels

The general strategy with spraying dispersant from boats or ships is to spray while heading to the wind, where possible, but spraying while heading with the wind is also acceptable in most circumstances.

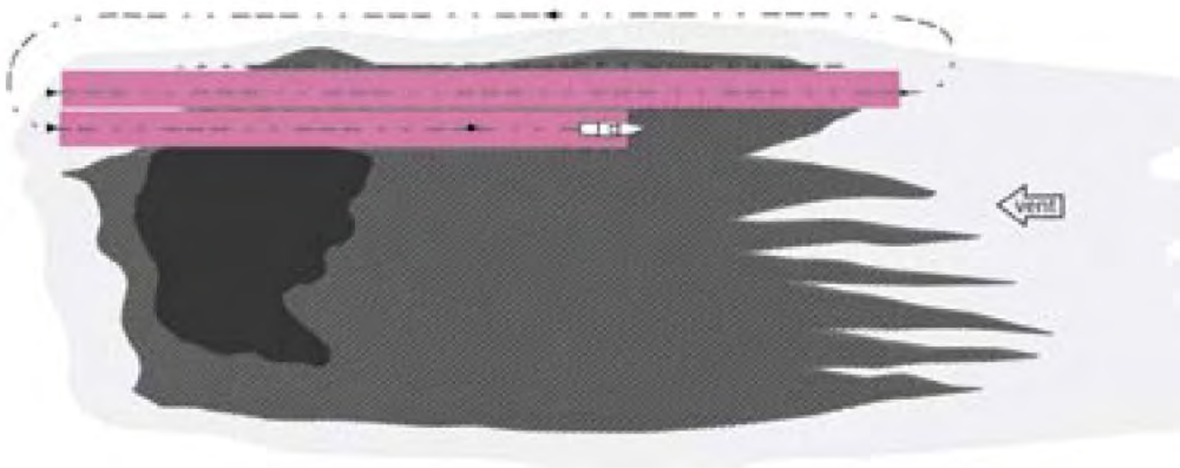


Figure 13. Spraying dispersant from ships and boats from the CEDRE publication "Traitement aux dispersants des nappes de pétrole en mer"

Spraying dispersant while the ship is heading into the wind causes the smaller droplets of dispersant spray to be blown backwards, and the largest droplets of dispersant contact the spilled oil first. Spraying dispersant while the ship is moving in the same direction as the wind can sometimes cause the fine part of the dispersant spray (containing the smaller dispersant droplets) of dispersant to be blown ahead of the main dispersant spray. On thin oil layers this can cause 'herding', where the dispersant droplets contact the water and cause the oil to contract into a smaller area. Subsequent dispersant spray will then mainly fall on the water surface and not on the spilled oil. This is not a problem on thicker layers of emulsified oil because it is not 'herded' by the dispersant.

For operational reasons, it is often preferred to maximize the amount of time spent spraying dispersant and minimize the amount of time spent manoeuvring the vessel. This can best be achieved by spraying in both directions whilst in the oil slick.

The speed of the vessel spraying dispersant can be varied to alter the dispersant treatment rate; spraying at 4 knots will deliver twice as much dispersant on the spilled oil as spraying at 8 knots.

There are practical limits to this speed variation. Any vessel needs a minimum forward speed to maintain directional control. Spraying at less than 2 knots is not really feasible. As a vessel moves faster it will generate a bow wave and this may displace the spilled oil out of range of the spraying system. The generation of the bow wave with speed depends on the specific vessel characteristics. The dispersant spraying system can be fitted as far forward as possible to counter the spilled oil displacement caused by the bow wave. The maximum speed for dispersant spraying varies with the vessel used, but is normally around 15 to 18 knots, although some vessels can spray dispersant at speeds higher than this.

In some instances it may be necessary to spray dispersant at an angle to the wind. This can be achieved by only using a single spray arm and using the vessel to shield the dispersant spray from the wind (Figure 14.)

Figure 14. Spraying dispersant at an angle to the prevailing wind

5.6 Spraying dispersants from aircraft

The main advantage of aircraft compared to surface vessels is their much higher speed that enables aircraft to reach a spill site much more quickly than a ship and enables them to quickly spray large areas of an oil slick with dispersant. The main disadvantages of aircraft compared to ships is the limited dispersant payload and the limitations to low flying, that is required to spray dispersant accurately, imposed by weather conditions.

5.6.1 Development of dispersant spraying from fixed-wing aircraft

In 1977, the UK Government conducted some initial experiments spraying dispersant from a Piper Pawnee crop-spraying aircraft. This single-engine aircraft could carry 550 litre of dispersant and had two spray arms (or 'booms'), one on each wing and each 4 metres long. Dispersant sprayed from an aircraft spreads out to form a 'carpet of dispersant in the air that gradually sinks onto the spilled oil. It was found that the deposited swath width of dispersant deposited by this aircraft spraying at approximately 80 knots and at an altitude of 3 to 4.5 metres was 16 metres. The operation of single-engine aircraft flying low over the sea is inherently unsafe in some respects; failure of the only engine would produce a dangerous situation.

The UK MPCU (Marine Pollution Control Unit) decided to use twin-engine PBN Islander aircraft for dispersant spraying. These aircraft had a dispersant payload of 1000 litres of dispersant and a spraying speed of approximately 50 knots. Six of these aircraft were placed under contract by the MPCU in the early 1980s, together with two DC-3 dispersant-spraying aircraft. The contract was justified by the use of an oil spill scenario of 5,000 tonnes of oil spilled, dispersant to be applied within 25 hours at a distance of 100 miles from a dispersant stockpile. The location of the hypothetical spill was to be anywhere within the UK Pollution Control Zone. A series of dispersant stockpiles were set up at airfields near the UK coast.

The UK capability for dispersant spraying from aircraft was significantly enhanced during the late 1980s. The dispersant-spraying fleet was increased to seven DC-3 aircraft and two DC-6 aircraft. Each DC-3 aircraft was capable of carrying 5 tonnes of dispersant and the DC-6 could carry 11 tonnes of dispersant. The DC-3 aircraft were used to spray 424 tonnes of dispersant at the *Sea Empress* oil spill in 1996.

A review of the aerial dispersant capability was undertaken in 2002 and the seven DC-3 aircraft were replaced by two Lockheed Electra L188 aircraft (Figure 14) as the major dispersant-spraying aircraft. The palletised spraying system consists of pumps and tanks that are secured to the floor of the cargo bay. Spray arms are externally mounted on either side of the rear fuselage. Each aircraft can deliver up to 15 tonnes of dispersant. The aircraft sprays at 140 knots and an altitude of 50 feet. Dispersant is delivered at rates from 5 to 22 tonnes per square kilometre.

Figure 14. Lockheed Electra aircraft spraying dispersant

A Cessna F406 can be fitted with a rapidly installed dispersant spray system. This system can be used for test spraying of dispersant, prior to larger-scale dispersant spraying from the Electra spray aircraft, or can be used alone on smaller oil spills. The dispersant spraying system consists of a removable tank. There is an electrically driven pump mounted in a dry bay in the tank and the spray arms (booms) are an integral part of the tank. The F406 can carry up to 1.5 tonnes of dispersant. The aircraft sprays at 130 knots from an altitude of 30 feet. Dispersant spraying from the both the Lockheed Electra aircraft and the Cessna F406 requires guidance from a controlling Cessna aircraft.

In addition to the aircraft chartered by the UK Government, there is the capability to spray dispersants from aircraft that is owned by OSRL (Oil Spill Response Limited). OSRL operate a Lockheed L-382 Hercules aircraft that can be fitted with an Airborne Dispersant Delivery System (ADDS Pack) (Figure 15) The ADDS Pack is a roll-on roll-off aluminium tank with a capacity of 5,500 U.S. gallons. Application rate from 2 centrifugal pumps is between 100-600 gallons/ minute. An adaptor frame supports 2 x 20 ft. booms, each with 44 nozzles. Total swath width is 150 ft. The application rate can be varied from 1-10 gallons/acre. There is a full remote control for all required functions.

The L-382 Hercules aircraft can also be operated with NIMBUS™ spray system (Figure 16) which is a modular system capable of carrying and spraying 12 tonnes of dispersant. The NIMBUS™ spray system is designed to be used with an L 382 Hercules aircraft, but it can be transported to site by any jet aircraft. Four tanks carry 3 tonnes of dispersant each. The pump unit (centrifugal) and spray-arm module spray dispersant with a swath width of 40 metres. The system can treat up to 10.4 km^2/hour.

Figure 15. Lockheed L-382 Hercules aircraft with Airborne Dispersant Delivery System (ADDS Pack)

Figure 16. Lockheed L-382 Hercules aircraft with Nimbus spray system

5.6.2 Development of dispersant spraying from helicopters

The use of fixed-wing aircraft for dispersant spraying requires the installation of the spraying equipment either inside or attached to the outside of the aircraft. With helicopters, there is the possibility of using a self-contained and under-slung spraying module.

In 1980 the UK Government investigated the use of a modified crop-spraying helicopter 'bucket' for spraying dispersants. This was a 180 gallon (810 litre) bucket from Simplex manufacturing Company of Portland, Oregon, USA. It has two 12 foot (3.9 metre) spray arms and is powered by a Briggs and Stratton 8 hp petrol engine. The helicopters used in the trials were a single-engine Hiller UH 12E with a carrying capacity of 450 kg and a twin-engine Aerospatiale 365 with a carrying capacity of 680 kg. The trials proved that the use of helicopters for spraying dispersant was feasible.

Subsequent developments were the Rotortech TC-3 with a 910 kg capacity in the UK, the SOKAF 3000 with a 3000 kg capacity in France and the Response 3000 with a 3000 kg capacity in Norway (Figure 17).

Figure 17. A Sikorski 61N helicopter reloading a RESPONSE 3000 dispersant spray bucket from dispersant stored onboard a support vessel

5.6.3 Operational guidance on spraying dispersants from aircraft

Spraying dispersant from aircraft requires very accurate flying at very low altitudes. It must only be undertaken by suitably qualified and trained crews. It also requires guidance from another aircraft since it is difficult to see the oil slick from the spraying aircraft when at such low altitudes.

When dispersant is sprayed from an aircraft it takes the form of a long 'carpet' of dispersant spray that hangs in the air and then settles slowly onto the spilled oil. It requires great skill and guidance to accurately spray dispersant from aircraft. Floating smoke canisters can be used to indicate the wind direction at the sea surface.

Spraying dispersants from aircraft should be undertaken from altitudes of between 30 and 100 feet while flying directly into the wind (Figure 18). If the wind has been in constant direction for some time, the thickest areas of the spilled oil will be in the form of windrows aligned with the wind and the dispersant spray should be deposited on these windrows.

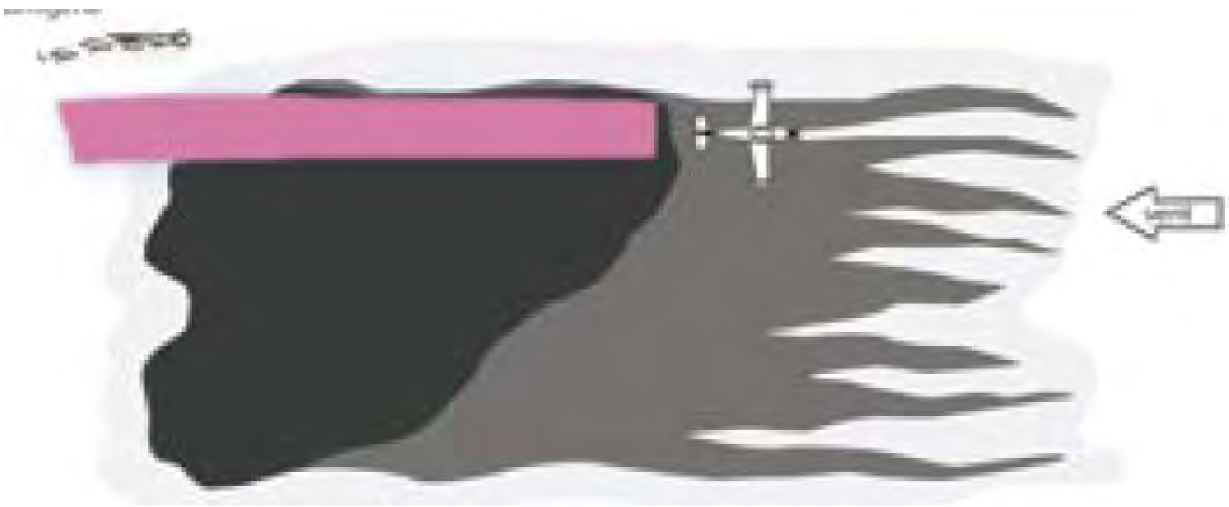


Figure 18. Spraying dispersant from a fixed-wing aircraft

In some circumstances it may be necessary to spray dispersant from aircraft at an angle to the prevailing wind direction (Figure 19). This requires a calculation of the amount of deflection needed to deposit the 'carpet' of dispersant spray in the air so that it will drift onto the spilled oil as it gently floats down under the influence of the wind.

Figure 19. Spraying dispersant from a fixed-wing aircraft at an angle to the prevailing wind

5.7 Monitoring the operational effectiveness of dispersants

5.7.1 Testing at the spill or conducting a test spray

Laboratory tests give an indication of the probable effectiveness of different oils after different degrees of weathering. These tests are good for predicting the probable effectiveness of dispersant spraying. If an oil spill has occurred, there is the opportunity to conduct an *ad hoc* test with dispersant on the oil in the condition that is actually in. A sample of oil can be taken from the sea surface, placed on seawater in a flask or jar and then dispersant, at approximately the recommended treatment rate, can be added. The dispersant-treated oil can then be gently mixed with the seawater in the jar and visual observation will show whether the oil is dispersing to any significant degree. Care should be taken that the test is at least a partially realistic simulation of the prevailing conditions; vigorous shaking of the oil and water mixture would indicate that dispersion would occur in very rough seas, but is not appropriate if the sea is not very rough. It would be preferable to use a standardised laboratory test method to conduct the test as this is less likely to be misleading, but the opportunity might not be available if the test apparatus and suitably trained technicians are at some distance from the spill site.

Whatever the expected performance of the dispersant, it is always useful to conduct a ‘test spray’ with dispersant before conducting large-scale dispersant spraying. An important element of this is the availability of observers who have previously witnessed a successful dispersant-spraying operation at sea, or at least in a large wave tank. The application of dispersant to an oil slick causes several easily visible effects; the oil ‘reacts’ to the spray by spreading out and being ‘herded’ by the dispersant. ‘Herding’ of oil occurs when dispersant hits clear water. The surfactants in the dispersant spread very rapidly across the sea surface and this pushes thin layers of the oil into much smaller areas. This effect subsides as the dispersant dissolves into the water. Oil that has been hit by dispersant spreads out to form a thinner oil slick. However, these visible effects are not indicators of dispersion, but the very obvious change in the appearance of the oil slick is often misinterpreted as being evidence of some dispersion. The only unambiguous visible sign of dispersion occurring is the formation of a light brown, opaque dispersed oil plume in the water column. This may not be instantaneous and it can take some time for such a plume to be visible to an observer.

As discussed in Section 4.2 it is currently impossible to accurately quantify how much spilled oil has been dispersed at any time after dispersants have been applied. No current remote sensing system can accurately measure the volume of oil on the sea surface, so it is not possible to quantify the effectiveness of dispersants at sea by remote sensing.

5.7.2 Visible cues that dispersion is happening

The successful use of dispersants can often be visually observed from surveillance aircraft or from boats; a light-brown plume or ‘cloud’ of dispersed oil will be observed in the water column under the oil slick (Figure 20). This plume of dispersed oil will move only with the currents in the water, while the oil slick on the surface will move under the influence of water currents and wind. The dispersed oil plume will slowly drift away from the oil slick and eventually become visible as a discrete plume in the water that slowly becomes less visible as the dispersed oil concentration decreases as dilution into the water column occurs.

Figure 20. Plume or 'cloud' of dispersed oil in the water

The problem with the visual observation of dispersing oil is that it can sometimes be ambiguous and it is not always observed if the viewing conditions are poor.

- Dispersant spraying onto high viscosity oils can be ineffective for the simple reason that the dispersant is washed off by waves before it has soaked into the spilled oil. The dispersant that is washed off can form a short-lived white cloud in the water. Discriminating between a white cloud of washed off dispersant and a light-brown cloud of dispersed oil is not easy. In strong sunlight, a cloud of dispersed oil can look very pale coloured and seem to be almost white. Similarly, washed off dispersant mixed in with a patchy oil slick can sometimes give the impression of a light-brown cloud of dispersed oil. An awareness of this possibility of this confusion, and preferably experience of seeing dispersants working (and not working) in controlled conditions at sea, is needed for an unambiguous interpretation of what is actually happening.

- It is necessary for the prevailing light to penetrate some distance into the sea so that any dispersed oil plume will be visible. This is achieved in bright sunlight, but in overcast conditions with low grey cloud, about the only thing that can be seen from most viewing angles is the reflection of the grey cloud and the sea appears grey. Any dispersed oil plume will not be easily visible.

Oil dispersed into the water is often visible of a light brown (*"café au lait"*), opaque plume (or 'cloud') in the water.

The cause of the opaque appearance of the brown plume of dispersed oil is light scattering caused by the very small oil droplets. In a similar way, light scattering by fat globules and casein micelles in cow's milk cause it to appear white and opaque. The fat globules in cow's milk have a VMD (Volume Median Diameter) of around 3 to 5 microns, small enough to cause light scattering. Although dispersed oil droplets are generally larger with a VMD of 70 to 100 microns (dependent on sea state; rougher seas will maintain larger oil droplets in suspension), a proportion of the smaller oil droplets will contribute to the opacity of the brown plume, provided that they are small enough and a present in sufficient concentration in the water.

As the oil is further dispersed and diluted into the water column the opaque, the dispersed oil concentration in water decreases and the light brown plume will become less visible; the plume will gradually fade from sight with time.

The visibility of the plume of dispersed oil depends on the prevailing conditions. With relatively clear water and when there is bright sunshine, the plume of dispersed oil in the upper water column will be easily visible for some time after the oil has been sprayed with dispersant. This is because the sunlight penetrates into the clear water and is reflected off of the dispersed oil plume. In such circumstances, the dispersed oil may appear to be a very light brown colour. If there is a high sediment load, or algal bloom, in the water it is much more difficult to see the dispersed oil plume because it rapidly becomes obscured. In grey, overcast conditions it is more difficult to see a dispersed oil plume because the diffuse light does not illuminate the plume as well as direct sunlight.

The plume of dispersed oil is best observed from the air, from a helicopter or fixed-wing aircraft, as a higher altitude permits a greater field of view. Observation of the plume from vessels might be limited by the position of the vessel relative to the dispersed oil plume. The range at which the dispersed oil plume might be seen is much more restricted from a vessel than it is from an aircraft. Additionally, the wake and “prop-wash” caused by the passage of a vessel through an oil slick that has been sprayed with dispersant might initiate dispersion in a localised area when the sea state is insufficient to cause dispersion of the entire slick. This could cause the misleading impression that the slick is dispersing when the majority of oil is not.

5.7.3 The use of monitoring equipment

Ultra-Violet Fluorometers (UVFs) can be used to accurately measure the dispersed oil concentration in the water column. This technique cannot be used to quantify the total amount of oil dispersed because it is impossible to simultaneously measure the dispersed oil concentration and the many different locations and depths below a dispersant-treated oil slick.

While it is impossible to accurately quantify the total amount of oil dispersed by the application of dispersants by UVF, it is possible to get a good indication of whether dispersion is happening in a localised area. The deployment of a UVF in a boat at the site of dispersant spraying can be used to take a measurement of the dispersed oil concentration in the water column before dispersant application and then repeat the measurement after the dispersant application. An increased dispersed oil concentration is a quantifiable indication that the dispersant is working. An absence of an increase in the dispersed oil in water concentration is an indication that the dispersant is not working.

Figure 21 shows the dispersed oil concentrations measured under an experimental oil slick along transects at three different depths (1, 5 and 10 metres) before the slick was sprayed with dispersant. Note that the scale is from 0 to 0.5 ppm (parts per million) of dispersed oil in water. At 1 metre depth the highest oil concentration measured was about 0.25 ppm and the average value across the transect was around 0.1 ppm. At greater depths the dispersed oil concentration was lower, peaking at about 0.15 ppm.

Figure 22 shows the dispersed oil concentrations measured under the same slick shortly after it had been sprayed with dispersant from a helicopter. Note that the scale is from 0 to 50 ppm - 100 times higher than that in Figure 21. The peak dispersed oil concentration under the slick rose to nearly 50 ppm at 1 metre depth, about 25 ppm at 5 metre depth and nearly 5 ppm at 10 metres depth. This is an obvious indication that the dispersant was causing substantial dispersion of the oil.

The UVF measurements of an increase in dispersed oil concentration in the water are a quantifiable indication that dispersion is working and can be obtained when viewing conditions are unsuitable for visual observation.

The information derived from measurements made with UVF fluorometers; the dispersed oil in water concentration profiles along transects under the dispersant-treated oil slick, can also be used as input for mathematical models that predict the diffusion of oil in the water column and its impact.

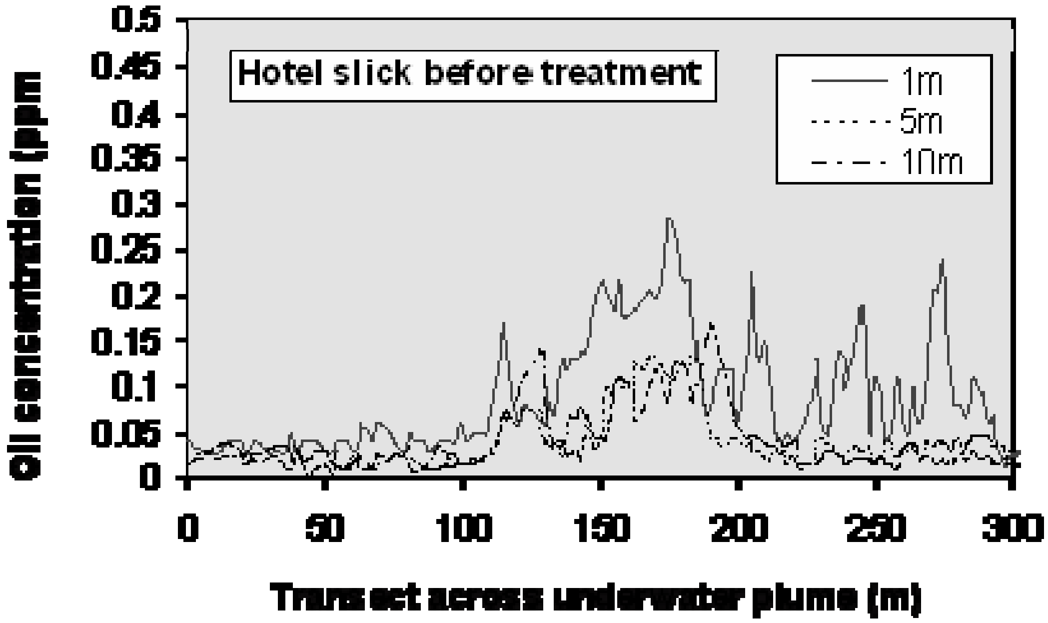


Figure 21. Dispersed oil concentrations beneath an oil slick

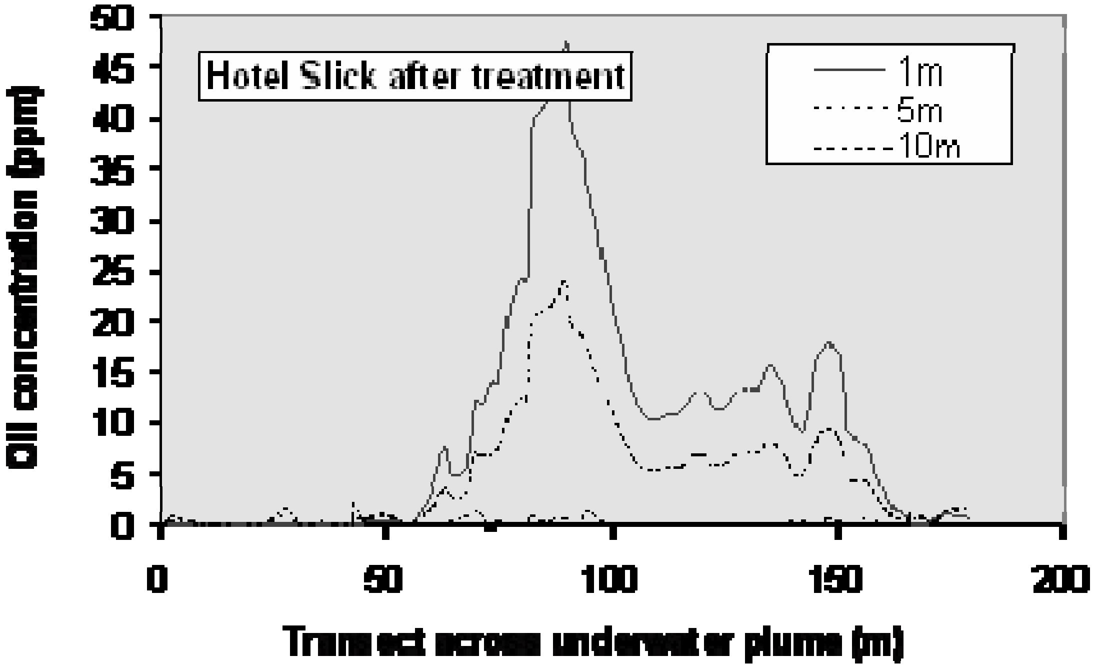


Figure 22. Dispersed oil concentrations beneath a dispersant treated oil slick

5.8 Health and safety in dispersant spraying operations

In most circumstances, dispersants will be sprayed onto spilled oil while the oil is some distance from the shoreline.

If the dispersant is sprayed from aircraft nobody will be exposed to the dispersant spray. The dispersant spray 'streams out' in the wake of the aircraft and - providing a properly designed spraying system is used - the crew of the aircraft will not be exposed to the dispersant spray. Because of the low altitude flying required for accurate spraying of dispersants all boats and ships (except the Dispersant Monitoring Team's boat) should be kept far from the oil being sprayed with dispersant for safety reasons; in order that the aircraft flying at very low altitude will not collide with the ship or boat.

If dispersant is being sprayed from surface vessels (boats or ships), it is possible that the crews of these vessels could be exposed to dispersant spray, especially if it is blown about by the wind. Suitable gloves, goggles, boots, and clothing should be worn, to limit the degree of exposure.

6. OIL SPILL DISPERSANTS IN EU / EFTA COUNTRIES

Most EU and EFTA countries have laws and regulations that prohibit the addition of chemicals into the sea without proper authorisation from the relevant national authorities. The addition of oil spill dispersants to spilled oil at sea is normally considered to be a circumstance where specific authorisation is required by a specified national authority. This may, or may not be, the national authority primarily concerned with oil spill response. Information about the policies of different countries to the use of dispersants is contained in *Inventory of national policies regarding the use of oil spill dispersants in the EU Member States* (available at:

http://www.emsa.europa.eu/Docs/opr/emsa_dispersants_inventory_2007.pdf.

There are 24 maritime nations in the EU and EFTA. Of these 24 countries:

13 countries (Belgium, Denmark, Estonia, Finland, Germany, Ireland, Latvia, Lithuania, the Netherlands, Poland, Portugal, Slovenia and Sweden) currently have no formal, standardised dispersant testing or approval schemes.

In some countries, such as Finland, Portugal, Slovenia and Sweden, no dispersant approval scheme is in place because dispersant use is prohibited or it is considered dispersants will **not be used** in oil spill response.

In other countries, for example Belgium, Denmark, Germany, Ireland, the Netherlands and Poland, dispersant use **may be considered** as a suitable response and dispersants approved in some other EU countries would be accepted.

7 countries (Cyprus, France, Greece, Malta, Norway, Spain and the United Kingdom) have testing schemes for dispersant toxicity and dispersant effectiveness and dispersant approval schemes.

The nations that may employ dispersants in oil spill response often have two levels of regulations about oil spill dispersants:

<u>Dispersant approval regulations</u>

These are regulations concerning the sale, purchase and stockpiling of dispersants before any oil spill incident. These regulations often require that any dispersant must be tested for toxicity and effectiveness before it can be used in waters under the countries control. Dispersants that have been tested and found to meet these dispersant approval procedures are then placed on a national approved oil spill response products list. Only dispersants that are on this approved products list can be used in oil spill response in the waters controlled by the country.

<u>Dispersant use regulations</u>

These are regulations concerning the use of oil spill dispersants in oil spill response at the time of an oil spill incident. These dispersant use regulations often describe a specified minimum water depth and a minimum distance from the shore at the locations where dispersants can be used. In other cases, specific areas where dispersants are not to be used are described on maps or charts. A summary of the national attitude to dispersant use and the dispersant testing and approval schemes of EU and EFTA maritime countries is contained in Table 8.

Country	Policy on dispersant use	Dispersant testing scheme	Dispersant approval scheme
BELGIUM	Allowed following prior official authorization from the Management Unit of the North Sea Mathematical Models (MUMM).	No standard dispersant testing scheme is in place.	No formal dispersant approval scheme is in place. Dispersants which have been approved for use by at least two of the contracting parties to the Bonn Agreement could be considered for use.
BULGARIA	The use of oil spill dispersants is not allowed	None / There is no standard dispersant testing scheme in place	None / There is no standard dispersant approval scheme in place List of approved dispersants: None / No list of approved dispersants exists
CYPRUS	Allowed following prior official authorization from the Director of the Department of Fisheries and Marine Research (DFMR).	The effectiveness and toxicity of dispersants are tested by the State General Laboratory of Cyprus	Dispersants which have been approved for use in other EU countries could be considered for use.
DENMARK	Allowed following prior official authorization from the Environmental Protection Agency (EPA), under the Ministry of Environment. In practice, oil spill dispersants have not been used in Danish waters for the past ten years	No standard dispersant testing scheme is in place, but the Danish EPA allows in general that dispersants approved for use in two to three other Bonn Agreement countries, can also be used in Denmark, without further requirements List of approved dispersants: None / No list of approved dispersants exists	No formal dispersant approval scheme is in place. Dispersants approved for use in 2 to 3 other Bonn Agreement countries could be considered for use.

Table 8. National attitude to dispersant use and dispersant testing and approval schemes of EU and EFTA maritime countries (as of 16/2007) Information from "EMSA Inventory of National Policies regarding the use of oil spill dispersants in the EU Member States".

Country	Policy on dispersant use	Dispersant testing scheme	Dispersant approval scheme
ESTONIA	Although the use of oil spill dispersants is in principle prohibited in Estonia, case by case permits to use dispersants in an oil spill situation may be issued by the Estonian Environment Inspectorate under the Ministry of Environment	No standard dispersant testing scheme is in place.	No formal dispersant approval scheme is in place.
FINLAND	Allowed following prior official authorization from the Finnish Environmental Institute (SYKE) Dispersants have not been used in Finnish waters since 1987 _______________________ The national contact point for the use of dispersants is the Environmental Damage Division of the Finnish Environment Institute	No standard dispersant testing scheme is in place.	No formal dispersant approval scheme is in place.

Table 8 continued. National attitude to dispersant use and dispersant testing and approval schemes of EU and EFTA maritime countries

Country	Policy on dispersant use	Dispersant testing scheme	Dispersant approval scheme
FRANCE	Allowed. No prior official authorization is required for dispersant use, since three geographical limits have been set along the French coast defining areas where dispersants can be used without major risk. The national contact point for dispersant use is CEDRE	1) Acute toxicity tests are performed by the marine biology laboratory in Concarneau, using the NF T90 349 test method and with the following selection criteria: the dispersant toxicity must be at least ten times lower than the toxicity of a reference toxicant (*Noramium DA50*) 2) Effectiveness tests are performed by CEDRE, using the NF T90 345 test method (the IFP test method) and with a 'pass mark' of 60% 3) Biodegradability tests are performed by INERIS, using the NF T90 346 test method, with the following selection criteria: the biodegradability of the dispersant should be at least 50%	Dispersants will be approved if they pass all 3 tests: efficiency first, toxicity and then biodegradability. Each approval is valid for five years. Only modern "Concentrate", UK Type 2 and UK Type 3 dispersants are approved.
GERMANY	Allowed following prior official authorization from the CCME (Central Command for Maritime Emergencies).	No standard dispersant testing scheme is in place.	No formal dispersant approval scheme is in place. Dispersants approved for use in the UK or France could be considered for use.
GREECE	Allowed following prior authorization from the Marine Environment Protection Division (MEPD) of the Ministry of Mercantile Marine, Aegean & Island Policy	The State Chemical Laboratory in collaboration with the National Centre for Marine Research is responsible for the control and testing of oil spill dispersants. Toxicity and effectiveness tests are performed on the dispersants	Dispersants which successfully pass the relevant toxicity and effectiveness tests are approved for use in Greece.

Table 8 continued. National attitude to dispersant use and dispersant testing and approval schemes of EU and EFTA maritime countries

Country	Policy on dispersant use	Dispersant testing scheme	Dispersant approval scheme
ICELAND	The use of oil spill dispersants is allowed following official authorisation from the Environmental and Food Agency ______ The national contact point for dispersant use is the Environmental and Food Agency	None / There is no standard dispersant testing scheme in place	None / There is no standard dispersant approval scheme in place ______ List of approved dispersants: None / No list of approved dispersants exists
IRELAND	The use of oil spill dispersants is forbidden unless authorised by the Irish Coast Guard	No standard dispersant testing scheme is in place.	No formal dispersant approval scheme is in place. Dispersants which have been approved for use in the UK could be considered for use.
ITALY	Allowed following prior authorization from the Ministry for Environment and Territory. The national contact point for the use of dispersants is the Antipollution Emergency Centre, GD for Nature Protection of the Ministry for Environment and Territory and Sea	Dispersant testing procedures are drawn up and approved by a group of technical experts from the following institutes: ICRAM, APAT, ISS and IRSA and include: - effectiveness, - toxicity, - stability, - bioaccumulation & - biodegradability tests of the dispersants' properties	There exists a Decree Law defining procedures for recognising the suitability of dispersant and absorbent products to be used at sea for the clearance of contamination by hydrocarbon oils was issued in December 2002. Dispersants have to pass several tests before they can be approved for use

Table 8 continued. National attitude to dispersant use and dispersant testing and approval schemes of EU and EFTA maritime countries

Country	Policy on dispersant use	Dispersant testing scheme	Dispersant approval scheme
LATVIA	The use of oil spill dispersants is in general prohibited in Latvian waters The national contact point for dispersant use is the Marine and Inland Waters Administration of the State Environmental Service, Ministry of Environment	No standard dispersant testing scheme is in place. Testing of hazards to human health is performed by the laboratory of the Latvian Environment, Geology and Meteorology Agency	No formal dispersant approval scheme is in place.
LITHUANIA	Allowed following authorization from the Environmental Protection Department of the Ministry of Environment.	None / Laboratory testing of dispersants is not being performed in Lithuania, which uses relevant information on laboratory dispersant testing performed in other countries	No formal dispersant approval scheme is in place. Usually, the company selling the dispersant has to provide the Environmental Protection Department of the Ministry of Environment with the exact description of the product, including a sanitary certificate, a safety data sheet of the product and other relevant information, against which the decision on the dispersant's approval is made, on a case by case basis

Table 8 continued. National attitude to dispersant use and dispersant testing and approval schemes of EU and EFTA maritime countries

Country	Policy on dispersant use	Dispersant testing scheme	Dispersant approval scheme
MALTA	The use of oil spill dispersants is allowed according to the NMPCP, following prior official authorisation from the Malta Environment and Planning Authority __________ The national contact point for dispersant use is the Director General of the Malta Environment and Planning Authority	Testing of dispersants is carried out by the University of Malta according to standard criteria.	A standard approval scheme for dispersants exists and is described in Malta's National Marine Pollution Contingency Plan __________ List of approved dispersants: Yes / A list of approved dispersants exists and is published in the NMPCP
THE NETHERLANDS	The application of dispersants is considered to be one of the response options. Conditions are defined based on sensitivity maps and seasonal data. __________ The national contact point regarding the use of dispersants is the RWS – North Sea, Netherlands Coast Guard Centre	In Bonn Agreement two contracting parties have test systems in place, UK and France. Moreover through the REACH programme suppliers of dispersants should test their products	N/A __________ List of approved dispersants: None / No list of approved dispersants exists

Table 8 continued. National attitude to dispersant use and dispersant testing and approval schemes of EU and EFTA maritime countries

Country	Policy on dispersant use	Dispersant testing scheme	Dispersant approval scheme
NORWAY	The use of oil spill dispersants is allowed in Norway on conditions specified in a regulation. Dispersant use must be documented as the combat strategy giving net environmental benefit in the pre-approved oil spill contingency plans before an incident occurs. In situations where dispersants would be beneficial, but their use has not been pre-planned, the Norwegian Pollution Control Authority (SFT) can authorise the dispersant use. ______________________ The national contact point for dispersant use in an emergency situation is the Norwegian Coastal Administration (NCA)	Dispersants have to pass toxicity and effectiveness testing. For activities that are producing, handling or dealing with oil, the IFP test method is being used, whereas for activities which are not producing or dealing with oil, the WSL test method is being used. SINTEF performs dispersant testing	Following the implementation of the new regulations, no list of approved dispersants is maintained by the authorities in Norway. The actual user of the dispersants has to ensure that the dispersants are tested both for toxicity and effectiveness, and keep records of these in case of inspection from the authorities (this is based on the internal control principle)
POLAND	Allowed following prior official authorization from the Director of one of the three regional Maritime Offices.	No standard dispersant testing scheme is in place.	No formal dispersant approval scheme is in place. The use of any dispersant (concentrates type 2 or 3) which has been approved for use in at least 2 Bonn Agreement Contracting Parties could be considered for use.
PORTUGAL	In principle, not allowed in Portugal, but may be allowed following prior authorization by the Ministries of Health and Environment.	No standard dispersant testing scheme is in place.	No formal dispersant approval scheme is in place.

Table 8 continued. National attitude to dispersant use and dispersant testing and approval schemes of EU and EFTA maritime countries

Country	Policy on dispersant use	Dispersant testing scheme	Dispersant approval scheme
ROMANIA	The use of oil spill dispersants is allowed in Romania, following prior official authorisation from the Ministry of Environment and Sustainable Development ______ In practice, oil spill dispersants have not been used in Romanian waters ______ The national contact point for dispersant use is the Ministry of Environment and Sustainable Development	None / There is no standard dispersant testing scheme in place.	None / There is no standard dispersant approval scheme in place ______ List of approved dispersants: None / No list of approved dispersants exists
SLOVENIA	The use of oil spill dispersants is prohibited in Slovenia due to the shallowness of Slovenian waters	N/A	N/A______ List of approved dispersants: None / No list of approved dispersants exists
SPAIN	The use of oil spill dispersants is allowed in Spain, following prior official authorisation from the respective representative of the maritime administration according to each case. ______ The national contact point for the use of dispersants is the Safety and Marine Pollution Section, of the DG Merchant Marine (DGMM) under the Ministry for Transport and Public Works.	For a dispersant to be approved, a biological and toxicological laboratory analysis of the product is being undertaken by a scientific institute dependent on the Ministry for Transport and Public Works. Dispersant testing is being performed by the Centro de Estudios y Experimentación de Obras Públicas (CEDEX).	and Public Works is responsible for the approval of dispersants and this approval must be renewed annually. In order for a dispersant to be approved, a biological and toxicological analysis of the product is undertaken by the CEDEX

Table 8 continued. National attitude to dispersant use and dispersant testing and approval schemes of EU and EFTA maritime countries

Country	Policy on dispersant use	Dispersant testing scheme	Dispersant approval scheme
SWEDEN	The use of oil spill dispersants is allowed following prior official authorisation from the response commander of the Swedish Coast Guard Sweden has not used dispersants in the past twenty years The national contact point for dispersant use is the Swedish Coast Guard Headquarters	No standard dispersant testing scheme is in place.	No standard dispersant approval scheme is in place.
UNITED KINGDOM	The use of oil spill dispersants is allowed in the UK, following prior official authorisation from the statutory licensing authorities, who are responsible for regulating their use at sea (MFA for England and Wales, FRS for Scotland and EHS for N. Ireland). Prior approval for dispersant use is needed in sea depths of less than 20 m or within 1 nm of such depths. The national contact point for the use of UK stocks of dispersants is the MCA.	Dispersants undergo an effectiveness and two toxicity tests: 1) Effectiveness test: The WSL test method, current test specification the WSL Report LR 448 2) Two toxicity tests: - Sea Test brown shrimp (products must not increase the toxicity of the oil) - Rocky Shore Test with limpets (products must not be more toxic than the oil alone) The effectiveness test is normally carried out by the National Environmental Technology Centre of AEA Technology PLC and the toxicity tests are carried out by the Centre for Environment, Fisheries and Aquaculture Sciences (Cefas).	Dispersants are approved for use by MFA (which acts on behalf of the other licensing authorities), and administers the product approval scheme. In order for an approval to be granted: - the interested party must complete an application form -dispersants must pass one effectiveness and two toxicity tests. .

Table 8 continued. National attitude to dispersant use and dispersant testing and approval schemes of EU and EFTA maritime countries

6.1 Regional Agreements

Because of the differing geographical location of the maritime EU member countries, they have entered into various regional agreements and bilateral arrangements with their neighbours to pursue matters concerning oil pollution of the sea.

The major regional agreements in Europe are:

- The Bonn Agreement (concerning the North Sea).
- The Helsinki Commission (HELCOM) (concerning the Baltic Sea).
- The Barcelona Convention (concerning the Mediterranean Sea).

Some EU member states are members of more than one regional agreement; for example, France has coastal areas on the Atlantic Ocean, the Manche (English Channel - part of the North Sea) and the Mediterranean Sea. These are detailed in Table 9.

The use of oil spill dispersants can be of regional, rather than purely national, concern:

- The contracting parties to Helcom have evolved a policy that is **not** to recommend the use dispersants in the Baltic Sea because of the nature of the Baltic Sea; an almost enclosed sea with large areas of shallow water and limited water exchange. This policy has recently been re-evaluated and dispersant use in some parts of the Baltic Sea may be considered in the future.

- The Bonn Agreement have evolved a policy that broadly accepts dispersants as a valuable response option to combat oil spills in the North Sea because there is sufficient water exchange and sea conditions can often limit the use of mechanical containment and recovery (booms and skimmers) in oil spill response.

- The general stance of the contracting parties to the Barcelona Convention to the use of dispersants in oil spill response in the Mediterranean Sea is intermediate to that of Helcom about the use of dispersants in the Baltic Sea, and of that of the Bonn Agreement about dispersant use in the North Sea; dispersant use should be limited to avoid possible ill effects by using dispersants in shallow water or areas of limited water exchange, but the recommendations are not as restrictive on dispersant use as those by Helcom for the Baltic Sea.

EU member countries that have territorial waters in two seas may therefore often have two discrete policies regarding dispersant use that apply to these two different areas. There is no logical discrepancy about recommending dispersant use in the Atlantic Ocean while taking a more restrictive view about dispersant use in the Mediterranean Sea. Both France and Spain have these distinctions made within their approach to dispersant use. Similarly, the attitude of Germany to dispersant use is internally consistent with both that of Helcom in the Baltic Sea and with that of the Bonn Agreement in the North Sea.

The apparently different national attitudes about dispersants of EU member countries, and the regulations about dispersant use that the relevant national authorities have introduced, are based on commonly accepted and shared principles of minimising the damage that might be caused by oil spills. The different emphasis of the regulations about dispersants often reflects more about the ecology and conditions that prevail in the different seas than being an apparent division or disagreement about the usefulness of dispersants in oil spill response.

EU member country	Maritime areas	Regional and Bilateral agreements on marine pollution
Austria	Not maritime	-
Belgium	North Sea	Bonn Agreement
Bulgaria	Black Sea	Bucharest Convention
Cyprus	Mediterranean Sea	Barcelona Convention / Egypt+Israel
Czech Republic	Not maritime	-
Denmark	Baltic Sea North Sea	Bonn Agreement / HELCOM/ Copenhagen Agreement / DenGer
Estonia	Baltic Sea	HELCOM / Russia + Finland
Finland	Baltic Sea	HELCOM / Copenhagen Agreement / Estonia+ Russia
France	Atlantic Ocean Mediterranean Sea	Bonn Agreement / Barcelona Convention / Lisbon Agreement / Manche plan + UK / Mediplan + Italy
Germany	Baltic Sea North Sea	Bonn Agreement / HELCOM / DenGer / NethGer / German-Swedish
Greece	Mediterranean Sea	Barcelona Convention / Greece + Italy
Hungary	Not maritime	-
Iceland	Atlantic Ocean	Copenhagen Agreement with Denmark, Finland, Norway and Sweden
Ireland	Atlantic Ocean	Bonn Agreement / Ireland + UK
Italy	Mediterranean Sea	Barcelona Convention / Mediplan + France / Italy + Greece
Latvia	Baltic Sea	HELCOM
Lithuania	Baltic Sea	HELCOM
Luxembourg	Not maritime	-
Malta	Mediterranean Sea	Barcelona Convention
Norway		Bonn Agreement / Copenhagen Agreement Russia in Barents
Poland	Baltic Sea	HELCOM / Poland + Russia / Poland + Germany
Portugal	Atlantic Ocean	Lisbon Agreement
Romania	Black Sea	Bucharest Convention
Slovakia	Not maritime	-
Slovenia	Adriatic Sea	Barcelona Convention
Spain	Atlantic Ocean Mediterranean Sea	Barcelona Convention / Lisbon Agreement / Bonn Agreement (observer)
Sweden	Baltic Sea	Bonn Agreement / HELCOM / Copenhagen Agreement
The Netherlands	North Sea	Bonn Agreement / NethGer
United Kingdom	Atlantic Ocean North Sea	Bonn Agreement / Manche plan + France / Norbrit + Norway / Ireland + UK

Table 9. Regional agreements between EU and EFTA maritime nations

6.2 Dispersant approval procedures

Dispersant approval procedures often require the dispersant manufacturer to submit samples of their oil spill dispersants for evaluation by government or laboratories. The tests carried out on the dispersants are designed to ensure that:

- The dispersant exhibits an acceptable degree of effectiveness.
- The dispersant is of sufficiently low toxicity to not pose a significant threat to the marine environment.

In addition, some dispersant approval procedures may require that:

- The dispersant is biodegradable
- The dispersant has suitable physical properties for spraying.
- The dispersant does not contain materials that may be hazardous.

6.2.1 Effectiveness testing procedures

Several different dispersant effectiveness test procedures are used by countries that have dispersant testing schemes.

As discussed in section 4.2.1, none of these laboratory methods are intended to be accurate simulations of the complex mixing and dispersion processes that occur when dispersants are used on spilled oil at sea.

Many different dispersant test methods have been developed around the world. In principle they are all similar; dispersant is added to test oil on seawater in a particular apparatus and the oil and water are mixed by some agitation method. After a specified period, the mixing may be stopped and a sample of the water containing dispersed oil is taken and analysed for oil content. The different methods differ in many details; the intensity of agitation and the relative volumes of oil and water are two of the most obvious. Different test methods produce different numerical results when the same dispersants and same oils are tested under otherwise identical conditions. Some tests are higher-energy tests than others.

The WSL method

The WSL (Warren Spring Laboratory) method (Figure 23) is used in the UK and Norway. 250 ml of seawater at 10ºC is placed in the conical flask and 5 ml of the test oil is placed on the water by using a syringe. The UK approval procedure uses a 2,000 mPa.s at 10ºC fuel oil and a 500 mPa.s at 10ºC fuel oil. The Norwegian approval testing uses emulsified fuel oil.

The required amount of dispersant is added. This is 2.0 ml for a UK Type 1 dispersant, 2.0 mls of a 10% dispersant / 90% seawater mixture for a UK Type 2 dispersant and 0.2 ml of a UK Type 3 dispersant. The dispersant is allowed to soak in for 2 minutes and then the flask is rotated at 33 $\pm$ 1 revolutions / minute for 2 minutes. The flask is then allowed to stand in a stationery and upright position for 1 minute and the 50 ml of the oily water is run off into a measuring cylinder. The oil is solvent-extracted from the water using dichloromethane. The solvent is dried by passing it through anhydrous sodium sulphate.

The amount of oil in the water is measured using a colorimeter at 580 nm and an absorbance calibration curve.

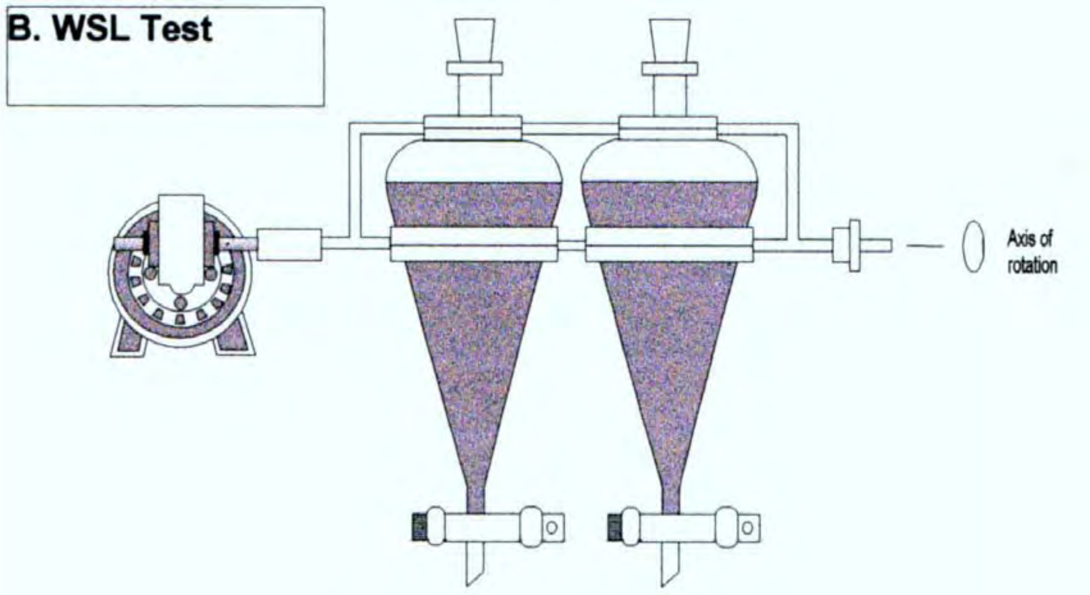


Figure 23. The WSL test apparatus

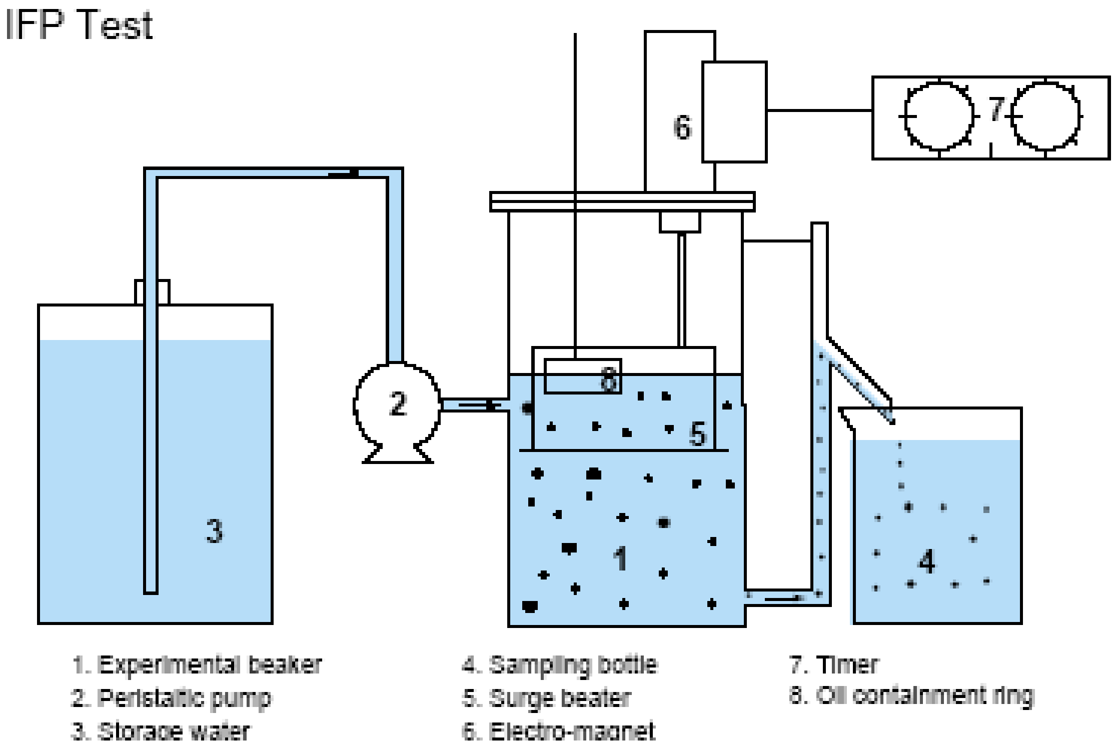


Figure 24. The IFP test apparatus

The IFP (Institut Francais du Petrole) method

The IFP method (Figure 24.) is used in France and Norway. 5 litres of seawater is placed in the glass container. 5 ml of the test oil is added to the water and 0.2 ml of dispersant is added from a syringe. The oscillating hoop supplies the mixing energy as it moves up and down a 15 mm path every 4 seconds. A continuous flow of water to produce a continuous dilution of 2.5 litres of water / hour is collected in the sampling bottle for one hour.

The oil is extracted from the water with dichloromethane and quantified using a spectrophotometer.

6.2.2 Toxicity testing procedures

A variety of toxicity procedures are used assess dispersant toxicity in the EU and EFTA countries that undertake such testing. They differ in several aspects, but the major difference is whether the dispersant is tested on its own or in combination with a test oil.

There is, for example, a difference in the philosophy in some parts of the toxicity testing carried out for approval purposes in France and in the UK.

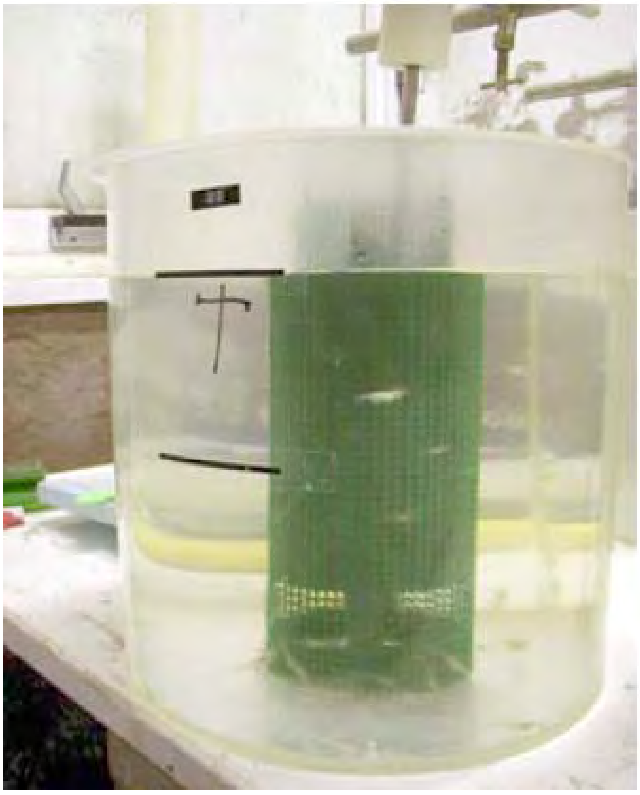


Figure 25. Test tank used in the NF T 90-349 toxicity procedure

The French toxicity test (NF T 90-349) (Figure 25) (details in **tests_toxicitie.pdf)** is conducted with white shrimps (*Palaemonetes varians*) or possibly on grey shrimp. The purpose of the NF T 90-349 is to ensure that any dispersant to be approved for use in French waters has a toxicity, as a assessed by a 6 hour LC50 procedure, is no more than 10 times that of the reference toxicant (NORAMIUM D.A. 50).

One part of the UK toxicity test procedure - the Sea test - (details in UK dispersant approval procedures.pdf) uses a very similar test organisms (*Crangon crangon*, the brown shrimp) and a very similar test apparatus, but the purpose is different. The UK test procedure uses a mixture of Kuwait crude oil and dispersant and compares the mortality of shrimp produced by this mixture with that produced by mechanically dispersed Kuwait crude oil. To pass the test and be approved for use the oil / dispersant mixture must be no more toxic than oil alone.

The second part of the UK toxicity test - the Rocky Shore test - uses limpets and compares the effects of spraying the limpets with dispersant and spraying them with oil. To be approved, the dispersant should be no more toxic than oil alone.

Several dispersants pass both the UK toxicity tests and the French toxicity test methods even though the philosophy of the test is different and the ‘pass level’ is different.

Norway uses the PARCOM Skeletonema toxicity test protocol for toxicity testing dispersants for approval purposes.

6.3 Dispersant use regulations

Most countries require specific prior permission from a national government agency before dispersants can be used anywhere in the waters under their control. Table 10 summarises the agencies that authorise dispersant use. This information was derived from that given in "EMSA Inventory of National Policies regarding the use of oil spill dispersants in the EU Member States" and other sources.

Several countries have regulations stipulating where dispersants must not be used, or where specific permission must be sought and granted before dispersants can be used. The general theme of these regulations is to prevent, or restrict, the use of dispersants on spilled oil in areas where the dispersed oil may cause harm to marine organisms. These areas are generally in shallow water or near specific ecological resources.

Some countries have specified particular minimum water depths where dispersants should either not be used, or can only be used only after specific permission has been granted by a Government authority.

The UK regulations require permission to be obtained from Defra (Department for Environment, Food and Rural Affairs) before dispersant is used on spilled oil in shallow water and, for legal reasons; shallow water is defined as being inside the "20 metre depth contour on the Admiralty chart, or within 1 nautical mile of such an area". See **Defra dispersants.pdf** for details

The Italian regulations describe specific geographical locations where dispersants must not be used and these are included in the Italian NCP (National Contingency Plan). Similarly, the use of dispersants in shallow water (less than 20 metres depth), or near particularly sensitive resources, would not be allowed.

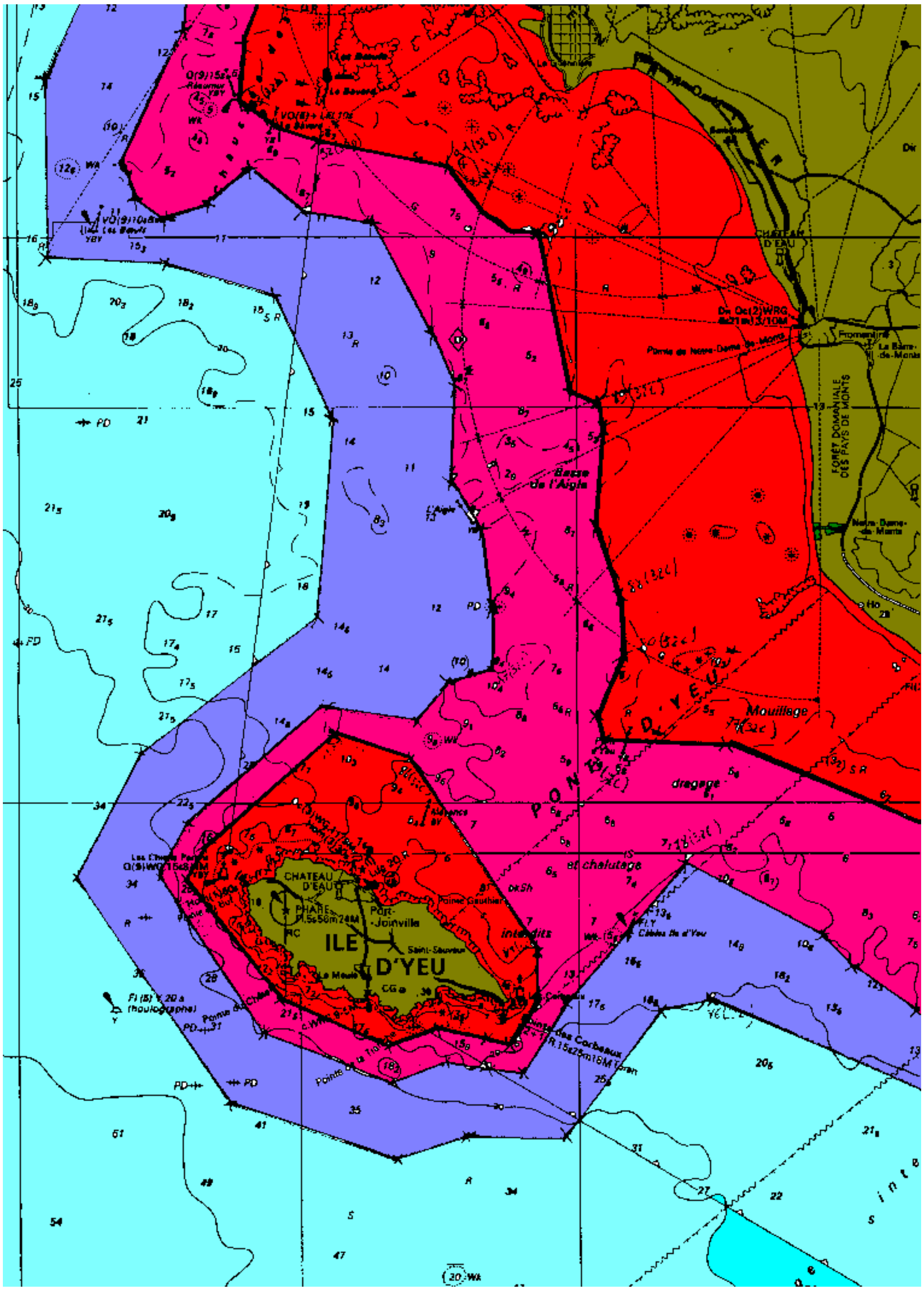
In France, the areas where dispersants can and cannot be used are defined by a combination of water depth, distance from the shore and quantity of oil spilled. Charts have been prepared of the entire coast of France and these have been divided into three zones where dispersants can be used on spills of 10, 100 and 1000 tonnes of oil. Figure 26 illustrates an example of this approach. Local sensitivities due to particular marine resources, current flow and seasonal variations are also taken into account in these charts.

Country	Authorization required for dispersant use
BELGIUM	Allowed following prior official authorisation from the Management Unit of the North Sea Mathematical Models (MUMM).
BULGARIA	The use of oil spill dispersants is not allowed
CYPRUS	Allowed following prior official authorisation from the Director of the Department of Fisheries and Marine Research (DFMR).
DENMARK	Allowed following prior official authorisation from the Environmental Protection Agency (EPA), under the Ministry of Environment.
ESTONIA	Although the use of oil spill dispersants is in principle prohibited in Estonia, case by case permits to use dispersants in an oil spill situation may be issued by the Estonian Environment Inspectorate under the Ministry of Environment
FINLAND	Allowed following prior official authorisation from the Finnish Environmental Institute (SYKE)
FRANCE	Allowed. No prior official authorisation is required for dispersant use, since three geographical limits have been set along the French coast defining areas where dispersants can be used without major risk. The national contact point for dispersant use is CEDRE
GERMANY	Allowed following prior official authorisation from the CCME (Central Command for Maritime Emergencies).
GREECE	Allowed following prior authorisation from the Marine Environment Protection Division (MEPD) of the Ministry of Mercantile Marine Aegean & Island Policy
ICELAND	Allowed following official authorisation from the Environmental and Food Agency
IRELAND	The use of oil spill dispersants is forbidden unless authorised by the Irish Coast Guard
ITALY	Allowed following prior official authorisation from the Ministry for Environment and Territory and Sea.
LATVIA	Prohibited.
LITHUANIA	Allowed following authorisation from the Environmental Protection Department of the Ministry of Environment.
MALTA	The use of oil spill dispersants is allowed according to the NMPCP, following prior official authorisation from the Malta Environment and Planning Authority
THE NETHERLANDS	The application of dispersants is considered to be one of the response options. Conditions are defined based on sensitivity maps and seasonal data. The national contact point regarding the use of dispersants is the RWS –North Sea, Netherlands Coast Guard Centre
NORWAY	Allowed. All companies in charge of oil operations (oil terminals, refineries, offshore oil fields) are obliged to consider and document dispersants as an oil spill response method in their contingency plans. The use of dispersants must be documented as a combat strategy in the pre-approved oil spill contingency plans before an incident occurs. In situations where dispersants would be beneficial, but their use has not been pre-planned, the Norwegian Pollution Control Authority (SFT) can authorise the dispersant use.
POLAND	Allowed following prior official authorisation from the Director of one of the three regional Maritime Offices.
PORTUGAL	In principle, not allowed in Portugal, but may be allowed following prior authorisation by the Ministries of Health and Environment.
ROMANIA	The use of oil spill dispersants is allowed in Romania, following prior official authorisation from the Ministry of Environment and Sustainable

	Development
SLOVENIA	Prohibited.
SPAIN	Allowed following prior official authorisation appropriate maritime administration.
SWEDEN	Allowed following prior authorisation from the response commander of the Swedish Coastguard.
UNITED KINGDOM	Allowed. Prior authorisation from the statutory licensing authorities (DEFRA for England and Wales, SEERAD for Scotland and EHS for N. Ireland) is needed in sea depths of less than 20 metres or within 1 nm of such depths.

Table 10. Authorisation of dispersant use

Figure 26. Dispersant use approval zones off the French coast



Land

Dispersion of 10 tonnes of spilled oil permitted

Dispersion of 100 tonnes of spilled oil permitted

Dispersion of 1000 tonnes of spilled oil permitted

6.4 Oil spill dispersants and spray gear available in EU and EFTA countries

Dispersants that have been approved by the national authorities, either on the basis of tests conducted by the relevant national authorities or by acceptance of dispersants approved in other EU countries, may be sold in EU and EFTA countries. However, a national approval for a dispersant is a pre-condition before any sale of that dispersant and is not an indicator that such sales have occurred. Many countries around the world have, over time, built up extensive lists of nationally approved dispersants, but very little or perhaps no dispersant is available for use in those countries.

The two main purchasers of oil spill dispersants are:

- Government departments that are responsible for oil spill response at the national level.
- Private industry, usually the oil companies, harbour authorities or privately owned oil spill response companies.

6.4.1 Total quantities of dispersant available

A total of just over 3,642 tonnes of modern "Concentrate" (UK Type 2, UK Type 3 and UK Type 2/3) dispersant are currently stockpiled in EU and EFTA countries, the vast majority contained in the UK and French stockpiles (Table 11).

Country	UK Type 2/3 dispersant in stockpiles (tonnes)	% of total in EU / EFTA stockpiles
United Kingdom	1400	39
France	1160	32
Greece	500	14
Norway	410	11
Malta	80	2
Italy	28	0.8
Cyprus	22	0.6
Belgium	20	0.6
Latvia	2	
Lithuania	2	
Total	**3624**	

Table 11. Stockpiles of dispersant in the EU / EFTA countries (as of 6/2007)

This total quantity of dispersant is, in theory, capable of dealing with a spill of 100,000 tonnes of oil at the generally recommended treatment rate of 1 part of dispersant to 20 or 30 parts of spilled oil.

The majority of the dispersant is held in government owned stockpiles; all but 60 tonnes (4%) of the entire amount of dispersant stockpiled in France is government owned. About 80% of the UK stockpile belongs to the UK Government. 224 tonnes (12%) of the dispersant stockpiled in the UK belongs to OSRL and could therefore be used anywhere in the world. The entire stock of approximately 400 tonnes of dispersant stored in Norway belongs to private companies.

6.4.2 Regional distribution of dispersant

The majority of dispersant is stored in NW Europe; in the UK, in Norway and in the French stockpiles on the Atlantic and Channel coasts (Table 12). A total of just over 3,000 tonnes of dispersant, theoretically capable of dispersing approximately 75,000 tonnes of spilled oil is close to the North Sea.

The amount of dispersant available for rapid use within the Mediterranean Sea is dominated by the French government Mediterranean stockpile of 654 tonnes and the additional 60 tonnes from the oil industry in France. This 714 tonnes is supplemented by the 248 tonnes of third generation dispersant in Greece and lesser amounts in Italy, Cyprus and Malta. Slightly over 1,000 tonnes of dispersant, theoretically capable of dispersing 25,000 tonnes of spilled oil, are potentially available for use in the Mediterranean Sea.

6.4.3 Brands of dispersant available for use from stockpiles

It was not possible within the time span of preparation of this report to identify the 248 tonnes of dispersants in Greece or the 28 tonnes of dispersant stored in Italy and the precise quantities stored in Spain and Portugal remain unknown, but are considered to be small.

Based on the information that was gathered, it appears that although 85 dispersant brands are currently, or have been recently, approved in EU and EFTA countries, only 15 different brands of dispersants are currently stored in stockpiles (Table 13). This number may need to be increased to account for the dispersants of unknown brand in the Greece, Italy, Spain and Portugal stockpiles.

The dispersants stocked in greater than 100 tonnes are:

- Gamlen OD 4000
- Dasic Slickgone NS
- Superdispersant 25
- Inipol IP 80
- Agma DR 379
- Dasic Slickgone LTSW
- Dispolene 36S
- Finasol OSR-52

These eight dispersants account for 3,780 tonnes or 94% of the total amount of dispersant currently stored in EU and EFTA countries.

Dispersant	Belgium	Cyprus	France (Manche)	France (Atlantic)	France (Med)	France Private	Greece	Italy	Latvia	Norway	UK Govt	UK Private	Total
Gamlen OD 4000			148*	120*	462*								**730**
Dasic Slickgone NS	10*								2*	400**	230*		**642**
Super-dispersant 25											595*	11**	**606**
Inipol IP 80			32*	218*	192*	60**							**502**
Agma DR 379											413*	15**	**428**
Dasic Slickgone LTSW											137*	257**	**394**
Unknown brands		22*					248*	28*					**298**
Dispolene 36S			107*	64*									**171**
Finasol OSR-52				34*									**34**
Oceania 1000				50*									**50**
Enersperse 1583											23*	20**	**43**
Corexit 9500											10*	30**	**40**
Dasic Slickgone EW												18**	**18**
Corexit 9527	10*									20**			**30**
Finasol OSR-51											73*	2**	**75**
Total	**20**	**22**	**287**	**486**	**654**	**60**	**248**	**28**	**2**	**420**	**1481**	**353**	**4061**

Table 12. Dispersant stockpiles in EU and EFTA countries (as of 6/2007)
** Government owned or privately held under government contract*
*** Privately owned*
Information from "EMSA Inventory of National Policies regarding the use of oil spill dispersants in the EU Member States" and other sources including CEDRE, the French Navy, UK MCA, NOFO and OSRL

Dispersant	Tonnes in stockpiles in EU and EFTA countries
Gamlen OD 4000	**730***
Dasic Slickgone NS	**642** (242* + 400**)
Superdispersant 25	**606** (595* + 11**)
Inipol IP 80	**502** (442* +60**)
Agma DR 379	**428** (413* + 15**)
Dasic Slickgone LTSW	**394** (257** + 137*)
Unknown brand	**298***
Dispolene 36S	**171***
Oceania 1000	**50***
Enersperse 1583	**43** (23* + 20**)
Corexit 9500	**40** (10* + 30**)
Finasol OSR-52	**34***
Dasic Slickgone EW	**18****
Corexit 9527	**30** (20** + 10*)
Finasol OSR-51	**75** (73* + 2**)

* *Government owned or privately held under government contract*
** *Privately owned*

Table 13. Dispersants currently stored in stockpiles (as of 6/2007)

6.4.4 Dispersant spraying capability

Table 14 contains the details of dispersant spraying equipment and dispersant in EU and EFTA countries.

Ship-based dispersant spraying capability

Nine of the 22 EU and EFTA maritime countries have absolutely no dispersant spraying capability from boats or ships. The dispersant spraying capability in most countries is very limited with only a few ‘stand-alone’ spraying kits that can be fitted to ‘vessels of opportunity’. France, Cyprus, Malta, Norway and Spain have some vessels with permanently installed dispersant spray systems.

Aerial dispersant spraying capability

The UK, France, Norway and Malta each have an indigenous aerial dispersant spraying capability while Ireland and Spain rely on services that would be provided by OSRL.

Country	Dispersant spraying from vessels	Dispersant spraying from aircraft	Dispersant stockpile
BELGIUM	The Federal Department of the Environment owns 4 units of Vikoma Vikospray 2000 ‘stand-alone’ ship mountable spraying arms.	None. If aerial dispersant application is required, aircraft application capacity would be requested from the UK	10 tonnes of Dasic Slickgone NS and approximately 10 tonnes of Corexit 9527 stored at Oostende Harbour
BULGARIA		None	None
CYPRUS	Vessel spraying capability is available. • Larnaca (2 units) • Paphos (1 unit) • Limmasol (8 units) • Paralimni (1 unit)	None	22 tonnes of dispersant are available in Limassol and Larnaca ports
DENMARK	None	None	None
ESTONIA	None	None	None
FINLAND	None	None	None

Table 14. Dispersant spraying equipment and dispersant stockpiled in EU and EFTA countries. (as of 6/2007)

Information from “EMSA Inventory of National Policies regarding the use of oil spill dispersants in the EU Member States” and other sources including CEDRE, the French Navy, UK MCA, NOFO and OSRL

Country	Dispersant spraying from vessels	Dispersant spraying from aircraft	Dispersant stockpile

FRANCE	France has 4 sea-going pollution recovery vessels, which are equipped with dispersant spraying arms.
	• AILETTE at Toulon with dispersant spray gear (2 x 9 m spray arms
	• ALCYON at Brest with dispersant spray gear (2 x 9 m spray arms)
	• CARANGUE at Toulon with dispersant spray gear (2 x 12 m spray arms)
	• ARGONAUTE at Brest with dispersant spray gear (2 x 9 m spray arms)
	The French Navy owns other shipboard dispersant spraying sets (16 for water-dilutable, UK Type 2 and 29 for concentrate, UK Type 3 dispersants) which can equip other vessels of opportunity, such as training vessels and tug boats.
		Aerial dispersant application is performed in France using the National Navy Super Frelon heavy helicopters.
		The French Navy owns 5 SOKAF 3000 helicopter buckets (3m² capacity each), stored close to Brest (3) and Toulon (2).
		2 helicopter buckets SIMPLEX type are owned by oil companies and stored close to Marseille.
			France maintains a stockpile of around 1,160 tonnes of dispersant:
			– 300 tonnes for the Channel area;
			  – Dispolene 36 S
			  – Gamlen OD 4000
			  – Inipol IP 80
			– 200 tonnes for the Atlantic Ocean, mainly at Brest;
			  – Dispolene 36 S
			  – Finasol OSR 52
			  – Gamlen OD 4000
			  – Inipol IP 80
			  – Oceania 1000
			– 410 tonnes for the Mediterranean
			  – Gamlen OD 4000
			  – Inipol IP 80
			– 5x50t in the over sea districts and territories
			There is also 60 tonnes of Inipol IP 80 at the FOST (oil company) base in Marseille

GERMANY	None	None	None

Table 14 (continued). Dispersant spraying equipment and dispersant stockpiled in EU and EFTA countries.

Country	Dispersant spraying from vessels	Dispersant spraying from aircraft	Dispersant stockpile
GREECE	The Greek government owns 10 multi-purpose oil spill combating vessels with dispersant spraying capability: The Greek government also owns 48 portable dispersant spraying systems with spraying arms for dispersant application from vessels. The EPE company maintains 2 units of PSEKA seaborne dispersant spraying systems and 1 Cooper Pegler CP 178 seaborne dispersant spraying unit	None	Stockpiles of 230 tonnes of 2nd generation and 248 tonnes of 3rd generation dispersants are kept. Dispersant stockpiles are allocated to various port authorities, port stations and antipollution vessels around the country.
ICELAND	None	None	None
IRELAND	Ireland does not have its own vessel or aircraft dispersant application capabilities. The Irish Coast Guard is an associate member of the OSRL in the UK, which maintains a large inventory of oil pollution response equipment, including dispersant spraying capability	The Irish Coast Guard is an associate member of the OSRL in the UK which has an aerial dispersant spraying capability.	None

Table 14 (continued). Dispersant spraying equipment and dispersant stockpiled in EU and EFTA countries.

Country	Dispersant spraying from vessels	Dispersant spraying from aircraft	Dispersant stockpile
ITALY	Shipboard spraying equipment (dispersant spraying arms) is available to the Italian government through arrangements with the private sector (Castalia Ecolmar).	None	28 tonnes of dispersants are available to the Italian government through arrangements with the private sector (Castalia Ecolmar).
LATVIA	A single diesel-driven dispersant spraying system designed for a vessel of opportunity can be installed on any vessel of the Latvian Coast Guard	None	2 tonnes Dasic Slickgone NS stored in Port of Liepaja.
LITHUANIA	Shipboard dispersant spraying equipment is 2 sets of "Simple Green" dispersant spraying equipment	None	1. 8 tonnes of Simple Green dispersant
NETHERLANDS	None	None	None
MALTA	Vessel application: • Tugs, patrol craft, workboats & Civil Protection craft are available to the Maltese authorities for dispersant application at sea	None.	Available dispersants are kept in the warehouse of the Oil Pollution Response Module (OPRM), 3 km from Valetta Harbour

Table 14 (continued). Dispersant spraying equipment and dispersant stockpiled in EU and EFTA countries.

Country	Dispersant spraying from vessels	Dispersant spraying from aircraft	Dispersant stockpile
NORWAY	Vessel dispersant application capability is available on several NOFO (Norwegian Clean Seas Association for Operating Companies) vessels and on vessels operating for oil companies	Dispersant application in Norway is performed by vessels using spray arms or by helicopter using either a 800 l bucket (one in Bergen and one in the Oslofjord) or a 3,000 l bucket (NOFO – one in Heidrun offshore area)	Approximately 400 tonnes of Dasic Slickgone NS are held in various locations by oil companies and on NOFO vessels and in land bases. In addition the oil refineries and oil terminals maintain minor quantities of dispersants (approx 30,000l).
POLAND	A single portable spray unit Vikoma Vikospray 1000, owned by SAR, is It is placed in Swinoujscie onboard vessel CZESLAW II	None	200kg of dispersant "SINTAN" At the SAR base in Swinoujscie
PORTUGAL	Limited vessel dispersant application capability is available.	None	A limited amount of dispersant stockpiles is maintained by the Navy at 5 stockpiles of pollution response equipment which are maintained by the Navy around the country
ROMANIA	None.	None	None.
SLOVENIA	None	None	None
SPAIN	The Directorate General of the Merchant Marine (DGMM) owns a limited amount of tug boats equipped with dispersant application capability and also charters tug boats from the private sector if needed	The Spanish Maritime Rescue and Safety Agency (SASEMAR) has an agreement with OSRL in the UK which offers Spain access to aircraft dispersant application capability	A limited amount of dispersant stock is available from the private sector

Table 14 (continued). Dispersant spraying equipment and dispersant stockpiled in EU and EFTA countries.

Country	Dispersant spraying from vessels	Dispersant spraying from aircraft	Dispersant stockpile
SWEDEN	None	None	None
UNITED KINGDOM	Two of the four MCA contract ETVs have a dispersant spraying capability, but this is incidental to their purpose of engagement and it is not anticipated that either would ever be used for dispersant spraying activities.	The UK uses primarily aircraft dispersant application capability: Two 4-engined turbo prop Lockheed Electra L188 aircraft, based at Coventry on six hours stand-by, with a capacity of up to 15,000 l of dispersant per aircraft. One Cessna F406 aircraft with a capacity of up to 1,500 l of dispersant, used more for small spills and test spraying of dispersant. Aerial surveillance: Two dedicated aerial surveillance aircraft, based at Coventry and used in conjunction with the dispersant spraying aircraft as top cover, while the spraying operations take place. OSRL operate a L-382 Hercules aircraft which can use either the ADDS Pack or the NIMBUS™ spray system	The MCA holds approximately 1,400 tonnes of dispersants in stock at: Huddersfield, East Kent, Coventry, Prestwick, Southampton, Saltash, Milford Haven, Northern Ireland, Inverness, Stornoway and Shetland The MCA stockpile consists of: • Superdispersant 25 • Agma DR 379 • Dasic Slickgone NS • Dasic Slickgone LTSW • Finasol OSR 51 OSRL has a stockpile of 224 tonnes of dispersant at several locations in the UK. The OSRL stockpile contains: • Dasic Slickgone LTSW • Corexit 9500 • Enersperse 1583 • Dasic Slickgone EW • Dasic Slickgone NS Another 100 tonnes of dispersant, mainly Dasic Slickgone LTSW, are stored by other oil spill response companies.

Table 14 (continued). Dispersant spraying equipment and dispersant stockpiled in EU and EFTA countries.

7. SUMMARY

Oil spill dispersants are an oil spill response technique that can be appropriate in some oil spill circumstances, provided that;

(i) Their use is likely to be effective (the spilled oil will be dispersed).

(ii) The temporarily increased dispersed oil concentrations in the water caused by the use of dispersants will not cause a disproportionate risk of harm being caused to marine organisms, compared to the benefit of removing the spilled oil from the sea surface, potentially reducing impacts to seabirds and the quantity of oil reaching the ashore.

Experience from extensive research and the use of dispersants at actual oil spill incidents, plus long term ecological monitoring following incidents such as the *Braer* incident in 1993 (where dispersant were prevented from being used effectively by the prevailing weather) and the *Sea Empress* incident in 1996 (where dispersants were responsible for preventing extensive shoreline oiling) indicates that:

c. The concerns that elevated dispersed oil in water concentrations have the potential to cause harmful effects are often overstated because the dispersed oil concentrations are rapidly diminished by natural dilution processes.

d. Dispersant use - in appropriate circumstances - can produce a demonstrable Net Environmental Benefit.

There is therefore a need to examine the individual circumstances of a particular oil spill to determine whether the use of dispersants is appropriate. The first step is to consider whether dispersants would ‘work’ on the spilled oil; i.e. will cause the oil to be dispersed in the prevailing weather conditions and sea state.

This can be achieved by considering the type of oil spilled and the dispersant available. This Manual and the associated software tool DUET (Dispersant Use Evaluation Tool) provide guidance in this step of the decision-making about the use of dispersants. This Manual contains Tables that act as general advice and the Decision Support Tool provides more specific advice by allowing the comparison of the properties of an oil that has not been previously subjected to testing with a set of ‘internal standards’ - oils which have been subjected to specific testing.

The second step is to consider whether there is a possibility that the elevated dispersed oil in water concentrations created by dispersant use have the potential to cause significant harm to marine organisms. The general guidelines on minimum water depths and proximity to coasts are described in this Manual, and the various national regulations (that often are based on such criteria) are referenced. If the decision-making process results in the consideration that dispersant use is (i) likely to be effective, (ii) unlikely to cause significant harm to marine organisms and is therefore (iii) appropriate, the next stage is to determine whether it is operationally feasible.

This Manual contains information that summarises the dispersants and dispersant spraying equipment available in EU and EFTA member states. Although no access to these resources belonging to individual member states, or private industry, can be guaranteed, the information of their current existence will aid timely decision-making. Guidance is also given on the operational aspects of spraying dispersants.

8. LITERATURE ABOUT OIL SPILL DISPERSANTS

A very large amount of literature has been published on all aspects of oil spill dispersants over the past 40 years. Several reviews and publications on specific aspects of oil spill dispersants have been written, including:

- 2007. EMSA. Inventory of national policies regarding the use of oil spill dispersants in the EU Member States
- 2005. Understanding Oil Spill Dispersants: Efficacy and Effects. Committee on Understanding Oil Spill Dispersants: Efficacy and Effects, National Research Council ISBN: 0-309-09562-X, 396 pages, 6 x 9, paperback
- 2005. CDERE Using dispersant to treat oil slicks at sea AIRBORNE AND SHIPBORNE TREATMENT RESPONSE MANUAL
- 2005. ITOPF (International Owners Oil Pollution Federation). THE USE OF CHEMICAL DISPERSANTS TO TREAT OIL SPILLS *TECHNICAL INFORMATION PAPER No. 4*
- 2005. Aurand, D. and G. Coelho (Editors). Cooperative Aquatic Toxicity Testing of Dispersed Oil and the "Chemical Response to Oil Spills: Ecological Effects Research Forum (CROSERF)." Ecosystem Management & Associates, Inc. Lusby, MD. Technical Report 07-03, 105 pages + Appendices Copies of this report can be obtained from: Ecosystem Management & Associates, Inc. website at: www.ecosystem-management.net
- 2001. DISPERSANTS AND THEIR ROLE IN OIL SPILL RESPONSE. IPIECA International Petroleum Industry Environmental Conservation Association *2nd edition, November 2001*
- 2001. Effects of Oil and Chemically Dispersed Oil in the Environment. Health and Environmental Sciences Department. API Publication Number 4693. Prepared under contract by: J.N. Boyd, J.H. Kucklick, D.K. Scholz, A.H. Walker, R.G. Pond and A. Bostrom. Scientific and Environmental Associates, Inc. Cape Charles, Virginia USA
- 2001. Effects of Oil and Chemically Dispersed Oil in the Environment. Health and Environmental Sciences Department. API Publication Number 4693 Prepared under contract by: J.N. Boyd, J.H. Kucklick, D.K. Scholz, A.H. Walker, R.G. Pond and A. Bostrom, Scientific and Environmental Associates Inc. Cape Charles, Virginia
- 2000. CHOOSING SPILL RESPONSE OPTIONS TO MINIMIZE DAMAGE *Net Environmental Benefit Analysis* IPIECA (International Petroleum Industry Environmental Conservation Association) available from http://www.ipieca.org
- 1999. A Decision-Maker's Guide to Dispersants. A Review of the Theory and Operational Requirements. Heallth and Environmental Sciences Department. API Publication Number 4692. Prepared under contract by: D.K. Scholz, J.H. Kucklick, R. Pond, A.H. Walker, A. Bostrom and D P. Fischbeck Scientific and Environmental Associates, Inc. Cape Charles, Virginia USA
- 1999. Fate of Spilled Oil In Marine Waters: Where Does It Go? What Does It Do? How Do Dispersants Affect It? An Information Booklet for Decision-Makers. Health and Environmental Sciences Department. API Publication Number 4691. Prepared under contract by: D.K. Scholz, J.H. Kucklick, R. Pond, A.H. Walker, A. Bostrom and D P. Fischbeck Scientific and Environmental Associates, Inc. Cape Charles, Virginia USA

- 1997. Putting Dispersants to Work: Overcoming Obstacles An Issue Paper Prepared for the 1997 International Oil Spill Conference. *Prepared by:* Alun Lewis and Don Aurand
- 1989. Using Oil Spill Dispersants on the Sea. Committee on Effectiveness of Oil Spill Dispersants, Marine Board, National Research Council ISBN: 0-309-03889-8, 352 pages, 6 x 9, hardback

The publications listed above contain many references

Hundreds off scientific papers have been written concerning all aspects of oil spill dispersants. These have been published in proceedings of conferences, notably:

- The International Oil Spill Conferences held in North America every 2 years from 1969 until 2005 and then in 2008. A searchable database is available: http://www.iosc.org/papers/search. This has over 2,800 papers, abstracts, and proceedings in the archive. Papers accepted for publication by IOSC for conferences in 1995, 1997, 1999, 2001, 2003 and 2005 are included. Abstracts since 1969 are included as are the full texts of proceedings since IOSC 1995.
- The Arctic and Marine Oilspill Program (AMOP) Technical Seminars held in Canada annually from 1977 until the present.
- The Interspill conferences held in Europe every 3 years since 2000
- The SPILLCON conferences held in Australia in 2000, 2002, 2004 and 2007.

Papers on dispersants have been published in many journals including:

- Marine Pollution Bulletin
- Environmental Science & Technology
- Environmental Toxicology & Chemistry
- Ecotoxicology & Environmental Safety
- Journal of Environmental Engineering
- Spill Science and Technology Bulletin (published from 1998 until 2002)

The Louisiana Universities Marine Consortium (LUMCON) has established a searchable database of references specifically on oil spill dispersants. This database is on line at http://www.lumcon.edu//library/dispersants and consists of nearly 2,000 citations found in the journals and conference proceedings listed above, plus government reports and 'grey' literature on research related to oil spill dispersants from 1960 to June 2008.

About EMSA

The European Maritime Safety Agency is one of the European Union's decentralised agencies. Based in Lisbon, the Agency provides technical assistance and support to the European Commission and Member States in the development and implementation of EU legislation on maritime safety, pollution by ships and maritime security. It has also been given operational tasks in the field of oil pollution response, vessel monitoring and in long-range identification and tracking of vessels.

http://www.emsa.europa.eu

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